Earthquake Seismograph Development: A Modern History—Part 2

Ben S. Melton

Introduction

Part 1 of this history covered the development of earthquake-type seismometers from 1948 into 1976. Part 2 covers the ancillary amplifiers, recorders, and timing systems which are required for complete observatories and which were developed over about the same time period mentioned. (The figures in this part are numbered continuously from part 1.) It is not immediately obvious how seismometer development depends on creation of appropriate amplifiers, nor how recorder improvement depends on amplifier output power available. Nor is it obvious that timing system design was initiated as an integral part of the observatory and that its functions have been modified as necessary with the advancing art.

For example, the effective sensitivity of Benioff's massive seismometers was limited to the optical magnification provided by a sensitive, low-frequency galvanometer, followed perhaps by magnification of the single trace on photographic film. Multiple traces on that same film could not be accommodated because a strong signal on one trace caused that trace to cross over adjacent traces. Recording of multiple traces required 'stiffer' galvanometers and an entirely new design of photographic recorder; and the less sensitive galvanometers required greater signal power to drive them. The limiting optical aperture also had to be considered. Eventually electronic amplification made possible the design of very small seismometers that could be installed in deep holes, away from local surface disturbances.

Although timing system development is not related to seismometer-amplifier combinations, it relates directly to the recording system and to the filing and recovery of data. Provision of a commercial-frequency power source made practical the use of available synchronous motors to drive recorders at constant speed; crystal frequency control with reference to universal world time allows recording of timing codes related to that time. Magnetic recording now justifies a timing code that permits high-speed automatic search for a specified time.

The Need for a Low-Frequency Seismograph Amplifier

Most modern seismographs use a coil moving in a magnetic field to deliver an electrical output to a galvanometer, the galvanometer consequently deflecting a light beam to make a photographic record. This is a satisfactory arrangement so long as there is no need to view the record before its photographic development. In such cases the galvanometer offers two advantages: It has no inherent 'one-over-f' noise, and its inherent natural period offers a means of filtering, to reduce the seismograph response outside the passband. This includes tidal accelerations and the long-term tilting of the earth's surface, which particularly affects horizontal seismometers. The chief disadvantages of a galvanometer are its reponse to mechanical vibration and its lack of ruggedness, particularly if it has a natural period of tens of seconds. In any case, there is a need for a more flexible system to avoid the photographic process.

At the beginning of the period covered by this history, there were no satisfactory low-frequency electronic amplifiers available, i.e., there were no electronic devices suited to amplifying the microvolt output levels of a seismometer at periods greater than 1 s. Therefore, in order to measure directly and record the seismometer outputs, 'chopper' amplifiers, built by the Perkin-Elmer Company in Glenbrook, Connecticut, were purchased for experimental service. These were called 'O.C. Breaker Amplifiers.' In these amplifiers, a motor drives two switch ('breaker') assemblies on a common shaft: one switch at the input, the other at the output. The switch at the input reverses the low-frequency ('D.C.') signal 150 times a second, and the resulting 75-Hz signal passes through a transformer to a conventional electronic amplifier. The amplified signal goes through another transformer and is rectified by the output switch assembly in order to restore the polarity of the input signal, which can be dc.

Genesis of the Galvanometer-Phototube Amplifier

The D.C. Breaker Amplifier was unsuited for constant field service, and efforts continued to locate or devise a satisfactory substitute. Then, by chance, my attention was directed to a similar need by the U.S. Coast and Geodetic Survey (USC&GS), headquartered in the Department of Commerce building in Washington, D.C. The Aleutian earthquake of April 1, 1946, (magnitude 7.4) caused a tsunami (tidal wave) which rolled across the Pacific and inundated the coastal area of Hawaii, resulting in great destruction of life and property. The USC&GS executive officer then offered to give immediate notification of future large earthquakes—not realizing that most seismographic observatories used photographic records which could not be viewed until after development.

In the Commerce building basement there was a seismometer whose output was used to drive a pen-and-ink recorder in an upstairs hall, for public viewing as earthquakes were recorded. This seismometer drove a conventional galvanometer. A light beam directed onto the galvanometer mirror was focused to a small spot on one edge of a slit, behind which was a photocell. As the galvanometer deflected the spot more or less onto the photocell, its conductivity varied, and the resulting output voltage was amplified by a conventional three-stage vacuum-tube amplifier that employed 1-μF coupling capacitors between stages. The amplifier output was connected to the recorder. The system worked, but coupling capacitor leakage was troubling, and strong input signals sometimes caused the amplifier to 'block' for several seconds.

Tom Pearce of the USC&GS was well aware of the difficulties mentioned and graciously accepted suggestions. I proposed the use of a double-cathode phototube, with the light spot directed so that half would fall on each cathode when the galvanometer was at rest. Then the phototube cathodes could be connected directly to vacuum-tube grids in a balanced (two-channel) amplifier with cathode follower outputs going directly to the recorder, which happened to have balanced driving coils. Such a system could be built without coupling capacitors and would amplify well at low frequencies. Also, as much of the system voltage gain would be in the phototube, the amplifier should not contribute objectionable noise. Such an amplifier circuit was built by Roger M. Wilson and Laurie R. Burgess in late 1949 [see *Wilson and Burgess*, 1962]. However, they cascaded two stages and used two phototubes, one on either side of a pair of mirrors set at right angles to each other. The adjoining mirror edges split the galvanometer light beam to direct the two portions into the phototubes. This system was quite satisfactory, and it established my credibility with Captain Elliott B. Roberts, the USC&GS executive officer—an important factor in the following episode.

By early 1951 the commercial laboratories under Air Force contract had not yet located or devised a satisfactory low-frequency amplifier, so I requested Roger Wilson to build a portable galvanometer-phototube amplifier for demonstration purposes. He gave me a clever arrangement in which the galvanometer signal was generated by a small magnet on the shaft of a clock motor that turned once a second in the field of a coil. The moving light spot from the galvanometer mirror was sensed, as before, by a double-cathode phototube in a bridge circuit, which was amplified by a cathode follower stage. The cathode follower output was biased to deliver alternately plus and minus 3 V, approximately.

Then, to assure ready acceptance of this galvanometer input principle, I took this prototype amplifier to a U.S. Signal Corps installation, where a 10-mile line of 'Spiral-4' telephone cable was available. There the amplifier output was connected to a cable pair at one end, and we proceeded to the other end of the line to measure the output. It was, as expected, alternately plus and minus 3 V—a silly, but politically useful, demonstration. This was July 20, 1961.

Richard A. Arnett of Geotech accepted the system in principle soon after my demonstration, and the Model 1450 phototube amplifiers were developed and in field service by November 1952. Figure A (cover) is a view of this amplifier, open to show its construction and controls. It had a balanced (two channel) cathode follower output which 'floated' above ground potential. It continued in field service until 1961. However, in 1956, NBS undertook its evaluation and suggested means of improvement. These suggestions, and a concentrated engineering effort that began in May 1957, resulted in a new design, Model 4300, which went into production in August 1958 together with a separate power supply and filter stage, Model 4304. Controls were simplified and stability greatly improved in this model, which provided a gain of about 100 dB and a dynamic range slightly greater than 70 dB. Its noise level appeared to be limited only by the thermal agitation of its input galvanometer. Figure B (cover) shows this model with its power supply, and Figure C (cover) reveals the arrangement of the galvanometer and other elements in the amplifier case.

In November 1959 the author talked with Hugo Benioff, Frank Press, Walter Ruska, and later with Forest K. Harris of NBS, suggesting that it might be advantageous to design a rugged long-period galvanometer specifically for seismograph use. Harris then undertook such a design, with some suggestions by D. P. Johnson, and the experimental construction and engineering was transferred to Geotech about April 1960. Figure 26 shows this galvanometer and its unusual details. It was incorporated in a long-period phototube amplifier, Model 5240A, shown in Figure 27.

Carrier Amplifiers

Although the galvanometer-phototube amplifiers were satisfactory in most respects, there was continuous pressure from electronic design engineers and others to replace the galvanometer. In part this was justified on the basis of lower costs and greater familiarity with electrical than with mechanical design. It could not be justified on the basis of a lower

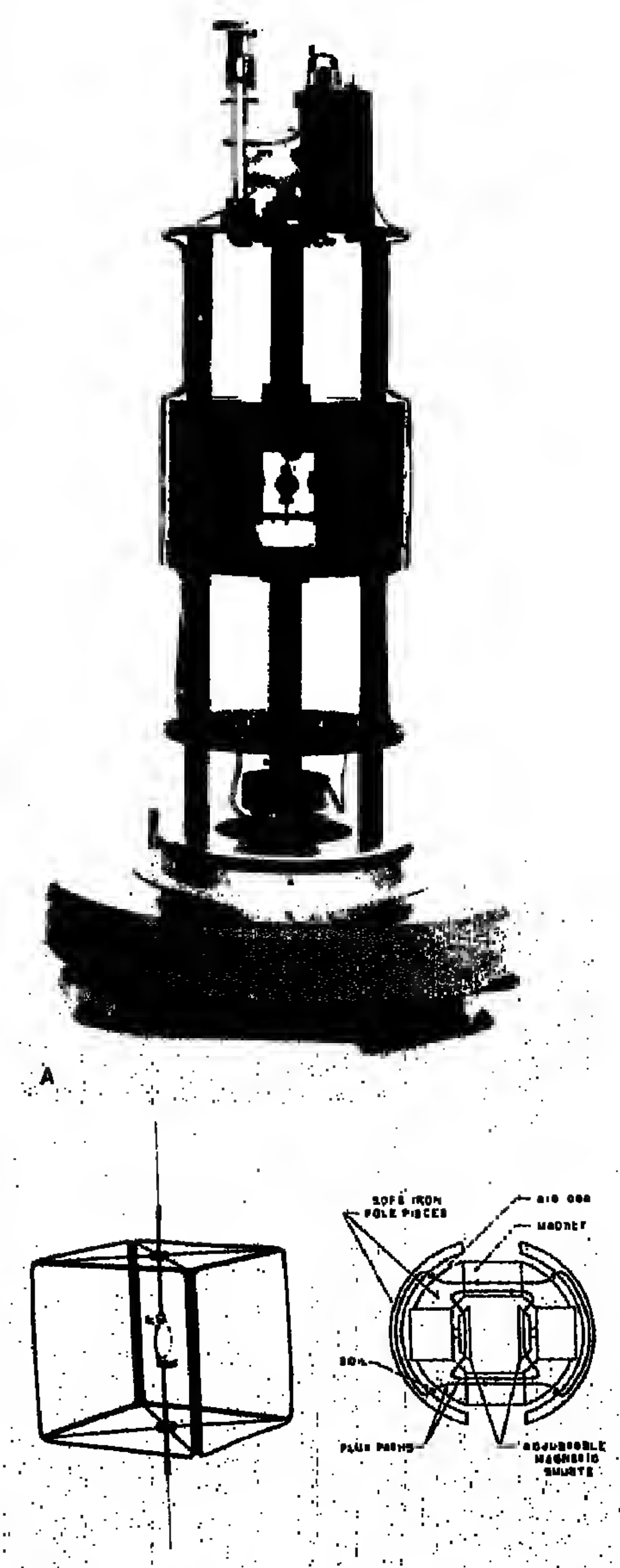

Fig. 26. Long-period galvanometer designed by F. K. Harris: (a) uncased view, (b) coil and mirror structure, (c) cross section of magnetic elements showing flux paths.

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Cover. (A) Model 1450 phototube amplifier with galvanometer input. This was the first production phototube amplifier designed for seismograph service. (B) Improved phototube amplifier with separate power supply and output filter. (C) Interior components of the phototube amplifier of (B). The galvanometer spot is centered by the knob on the front panel. (For more information, see article by Melton, this page. Part 1 was published in May 26 *EOS*.)

Particles and Fields—Ionosphere

5510 Auroral zone magnetic effects
SIMULTANEOUS OBSERVATIONS OF AURORAL ZONE ELECTRODYNAMICS BY TWO SATELLITES: EVIDENCE FOR HEIGHT VARIATIONS IN THE TOPSIDE IONOSPHERE
B.J. Rich (Eagle College, Newton, MA 02183)
C.A. Cattell, M.C. Kelley, W.J. Burke

The S3-2 and S3-3 satellites were launched into orbits with identical inclinations but with apogees of 1500 and 8000 km, respectively. Both satellites were equipped to measure magnetic fields, electric fields and energetic electrons. By comparing a few cases when the satellites were crossing the auroral zone at approximately the same universal time and location, altitude variations in the electrodynamics of the auroral zone can be separated from universal and local time variations. Such comparisons show that there are times when the field-aligned current per unit of flux in the auroral zone measured by magnetic field deflections at the two satellites is the same at both altitudes. There are also times when the field-aligned current per unit of flux is larger at high altitudes than at low altitudes. This requires flux and currents perpendicular to the magnetic field. Comparisons of the convection electric field (scale size > 0.1°) at the two altitudes show that the electric field does not always map as though field lines were equipotentials. In addition, intense, small-scale (< 0.1°) electric fields perpendicular to the magnetic field, previously associated with electrostatic shocks, which are observed at high altitudes are usually not seen in simultaneous low altitude observations. Only in one of the six passes was there a simultaneous observation of a region of intense, small-scale electric field variations at 800 km and 1000 km. (Field Aligned Currents, Auroral Zone, Electrostatic Shocks)
J. Geophys. Res., Blue, Paper 1A0781

5519 Interactions between waves and particles
FORMATION OF A CONICAL DISTRIBUTION AND INTENSE ION HEATING IN THE PRESENCE OF HYDROGEN CYCLOTRON WAVES
G. Okuda and M. Ashour-Abdalla (Department of Physics and Institute of Planetary Physics, University of California, Los Angeles, CA 90024)

It is found, by means of numerical simulations, that if the electron velocity distribution is maintained by a constant production of electrons, electrostatic hydrogen cyclotron (EHC) waves driven by the electron drift grow to a large amplitude ($e\phi/T_e \simeq 1$) resulting in the formation of a conical velocity space distribution ($T_\perp \gg T_\parallel$) and strong ion heating perpendicular to the magnetic field. The nonlinear saturation is characterized by the presence of a single coherent mode which dominates all the others. The ion heating rate and the temperature anisotropy agree reasonably well with quasilinear theory. Comparisons of the simulation results with the observations of EHC waves and the ion velocity distribution along auroral field lines are discussed.
Geophys. Res. Lett., Paper 1L0562

5540 Ion densities and temperatures
ON THE MAINTENANCE OF THE VENUS NIGHTSIDE IONOSPHERE: ELECTRON PRECIPITATION AND PLASMA TRANSPORT
V. C. Knudsen (Lockheed Palo Alto Research Lab., Dept. 52-12, Bldg. 205, 3251 Hanover Street, Palo Alto, CA 94304) K. Spenner, R. C. Whitten, J. R. Spreiter, K. L. Miller and V. Novak

Suprathermal integral electron spectral between 3 and 45 eV measured by the ... RPA are presented for the Venus nightside ionosphere. The observed integral electron flux is relatively constant with time and altitude. The simultaneously measured plasma density is much more variable and not correlated with the electron flux. For a typical electron spectrum the ionization rates and the ion density height profiles for O^+ and O_2^+ are calculated for 10 and 10 degrees magnetic dip angle. The O^+ and O_2^+ ion density height profiles are also calculated for a downward flux of O^+ ions at 10, 40, and 90 degrees magnetic dip angle. Comparison of the numerical modeling results with median profiles of O^+ and O_2^+ ions measured by the RPA reveals that a downward flux of O^+ ions of between 1 and 4×10^8 cm^{-2} s^{-1} satisfactorily reproduces both the O^+ and O_2^+ measured median nightside density profiles. The typical suprathermal electron spectrum produces an O_2^+ density profile with peak density approximately half that typically observed and produces an O^+ profile which is about an order of magnitude too small. From the evidence presented in this paper, from previous measurements of adequate O^+ transport across the Venus terminator and from interpretation of ion thermal measurements, we conclude that transport of O^+ ions from the dayside ionosphere is responsible for most of the ionization rate required to maintain the nightside ionosphere. Variation in the O^+ transport mechanism is primarily responsible for the large variation of the nightside ionosphere density. Suprathermal electrons provide a relatively constant ionization rate which is of the order of one-fourth that of O^+ transport and which contributes principally to the O_2^+ peak. (Venus, electron precipitation, ionosphere, nightside, plasma convection)
J. Geophys. Res., Blue, Paper 1A0591

5515 Ionospheric disturbances
GRAVITY WAVE INITIATION OF EQUATORIAL SPREAD F: A CASE STUDY
M.C. Kelley, M.F. Larsen (School of Electrical Engineering, Cornell University, Ithaca, NY 14853), C. LaHoz, and J.P. McClure

Jicamarca radar backscatter maps were made during four consecutive nights in March, 1979. Two of these maps displayed single towering plumes extending to nearly 1000-km altitude. On a third night, discussed in detail here, six plumes were generated in clear association with a nearly sinusoidal oscillation of the height of the bottom side of the F layer. The vertical amplitude of the oscillation was several hundred kilometers and the period about 100 minutes. The plumes were generated either when the bottom side of the F layer was at the highest altitude or in the descending phase of the motion. Families of curves are presented which correspond to the solution of the dispersion relation for gravity waves capable of initiating the observed bottomside oscillations via the spatial resonance mechanism. We conclude that the solutions thus derived are reasonable and present a criterion for how well matched the gravity wave phase velocity and plasma drift have to be to produce a given perturbation in the ionization density. This criterion indicates that although initiation by a gravity wave seems likely, the gravity wave interaction cannot yield the large displacements observed without further amplification by the Rayleigh-Taylor instability. Finally, we show that the preferential generation of plumes during the descending phase of the F-layer height oscillation can be explained by a generalized Rayleigh-Taylor instability operating on the distorted ionosphere ... the destabilizing effects of gravity ...

5545 Ionospheric disturbances
REVIEW OF RECENT PROGRESS IN IONOSPHERIC PREDICTIONS
K. Davies (NOAA/ERL/Space Environment Laboratory, Boulder, CO. 80303)

This paper reviews the state of ionospheric predictions following the Solar-Terrestrial Predictions Workshop held in April 1979 at Boulder. The review includes: the various uses of the ionosphere, the physical bases, long-term and short-term variations, the techniques used for their prediction and the current state-of-the-art of ionospheric predictions. The different requirements of various users (system designers and planners) are discussed together with the needs for timely dissemination systems.

Because ionospheric predictions and forecasts have been underway for many years, the advances have been of second order. The main advances include the incorporation of features such as the auroral oval, the magnetospheric cleft, the mid-latitude trough, etc; the positions of which vary with local time and solar-terrestrial activity. Other advances include: four-dimensional models of the ionosphere, which yield electron density profiles useful in raytracing; some new methods for predicting E-layer and E_s-layer characteristics; transionospheric propagation, which requires prediction of total electron content and scintillation characteristics. In recent years, advances have been made in the use of empirical and physical models of the ionosphere.

Short-term ionospheric forecasting has also progressed in recent years primarily through technological advances in data acquisition (e.g. satellite sensors), data processing (computers) and dissemination of information. Nevertheless, solar forecasting -- a vital ingredient of magnetic/ionospheric storm forecasting -- is still largely an art in which the forecasters' experience and skill, in recognizing and interpreting solar features, plays the dominant role.
Rad. Sci., Paper 1S0738

5563 Plasma motion, convection or circulation
SOME GENERAL CHARACTERISTICS OF UPFLOWING ION BEAMS OVER THE AURORAL ZONE AND THEIR RELATIONSHIP TO AURORAL ELECTRONS
H. L. Collin (University of Southampton, Southampton, United Kingdom) R. D. Sharp, E. G. Shelley, and R. G. Johnson

Data from the Lockheed ion mass spectrometer and electron spectrometer on the polar orbiting satellite S3-3 were used to determine some of the general characteristics of upflowing beams of protons and oxygen ions at an altitude of about one earth radius above the auroral regions and their relationship to auroral electrons.

Ions of both species were found with ... throughout the range of the instrument ... keV. The energies of the two ion species were well correlated with one another. The oxygen energy almost always exceeded the proton energy and was, on the average, 1.7 times higher ... average energy of the accompanying electrons ... also correlated with the ion energies and ... usually intermediate in value. The fluxes of ... and electrons appeared to behave ... independently of one another, but the fluxes were ... to be limited in their ranges. Proton fluxes ... 10^9 (cm^2 s sr)$^{-1}$ and oxygen ... 5×10^7 (cm^2 s sr) ... loss cone always exceeded ... The results of this study ... principally energized by ... electric field and that ...

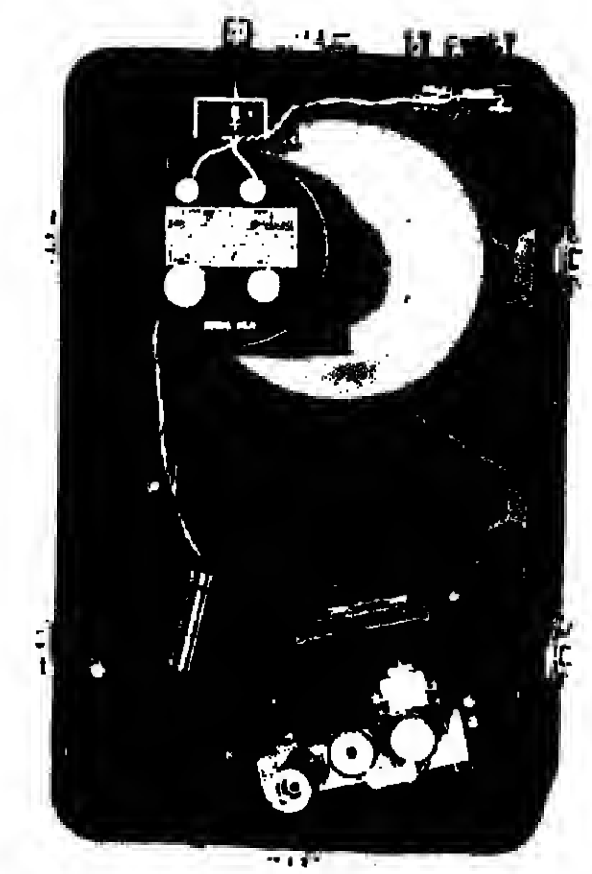

Fig 27. Long-period phototube amplifier that incorporates the Harris galvanometer.

noise level, at least in principle, as thermal agitation noise would be the limit in any case. But the noise that increased with period could be avoided by performing all amplification at high frequencies. In such a system, the low-frequency signal mixes with a high-frequency carrier in some type of modulator, which should not itself inject appreciable noise or distortion. The resulting carrier with sidebands is then amplified and, at a higher power level, demodulated, again with negligible distortion, to recover the low-frequency signal, which can be digitized if desired.

In August 1962, Texas Instruments made available to NBS their new 'reactance' amplifier to be tested and evaluated. Different models of this amplifier bore the designation RA, followed by a model number. The modulator in this amplifier employed a pair of voltage-controlled solid-state capacitances, some diodes, and bias cells. A high-frequency oscillator supplied the capacitance control voltage, so that any low-frequency signal was modulated 'parametrically' to produce a carrier with attendant sidebands. The carrier with sidebands was amplified at high frequency and subsequently demodulated to recover the low-frequency signal. This amplifier was described by its inventor *Baird* [1963] and also by *Davis* and *Ezell* [1963]. The amplifier was relatively noise-free when connected to an input impedance on the order of 500,000 ohms, but it exhibited input current noise when connected to much lower impedances. There is a practical difficulty in winding a 500,000-ohm coil for a seismometer without obtaining leakage or short circuit between some of the turns. In any case, there remains the thermal agitation noise of the input impedance.

In 1969, ITHACO Inc. of Ithaca, New York, devised a prototype 'chopper' amplifier, Model 6069-74. This amplifier was packaged by Geotech and subsequently used in every channel of the long-period array of symmetrical triaxial seismometers installed in Alaska. In this amplifier the low-frequency signal was chopped at carrier frequency with an electronic switch composed of field-effect transistors. The resulting carrier was amplified, demodulated, and passed through appropriate filters to provide high-frequency cutoff and to limit long-term drift. Essentially this same amplifier was encased by ITHACO and sold as Model 154.

Figure 26, taken from the paper by *Melton* [1976], shows the noise spectra of several amplifiers when connected to different input impedances. All amplifiers tested showed steeply rising noise at long periods, probably originating in stages after demodulation. The phototube amplifier with a 30-s galvanometer shows a hump in the noise response spectrum near the galvanometer period, as expected. The rising spectrum at *shorter* periods was not investigated, but it could be from a parasitic mechanical mode of the galvanometer, the electrical resonance of the coil inductance and distributed capacity, or just the effect of post-galvanometer noise when such noise spectrum is divided by the galvanometer response function (that is, referred to the input).

After the ITHACO amplifiers were put in service on the long-period array channels, it turned out that the chopper switching process put carrier spikes into its broadband carrier amplifier. These spikes 'choked' the carrier amplifier, limiting its gain and therefore the input to post-demodulator stages, causing these stages to show their long-period noise. In view of this field experience, O. D. Starkey designed an amplifier in which the carrier stages were limited to a very narrow band so that any switching transients would be suppressed. This amplifier, Geotech Subassembly 33330, eventually replaced the ITHACO amplifiers in the symmetrical triaxial array. The amplifier's long-period noise at 100 s was less than 4 dB above its input thermal noise level. Its noise response spectrum appears in Figure 6 of Melton's paper.

The above carrier-type amplifiers were designed to accept a low-frequency electrical signal; but if the basic requirement is altered, i.e., made to sense displacement of a seismometer mass, the modulation function can be performed in a varying capacitor attached to the mass and frame. This has been done in various seismometers in the past, including the DTMB and NOL seismometers discussed in part 1. It is a most important feature of the Geotech Model 36000 seismometer and will undoubtedly be a feature of many future designs, perhaps even displacing the electrodynamic system. However, this change has many ramifications, not the least of which is the increased dynamic range and resolution requirement.

Preferred Forms of Seismograph Records

The art of seismology depends upon visual interpretation of seismograph records by experienced seismologists. In this connection, magnetic tape is useless, columns of figures even more useless, and computer analysis is questioned unless it agrees with the seismologist's interpretation. Therefore, the final form of recording should be tailored to a human's visual appreciation, in the broadest sense. If for valid reasons part of a seismograph system employs magnetic tape or digital processing, the final presentation, even on a cathode ray oscillograph, should be in a form for human perception.

The earliest form of visible seismograph record was made by mechanical seismographs, which usually had lever systems to magnify the motion of the heavy mass with respect to the instrument frame; the lever system terminated in a scriber that rested on smoked paper which was pulled along to provide a relative time axis. This recording system had a considerable dynamic range, perhaps 60 dB, if the ratio of scribed line to maximum amplitude is the measure. Photographic traces seldom showed this much resolution, but they could be produced by galvanometers in the more flexible electrodynamic systems. We now follow the development of recording systems.

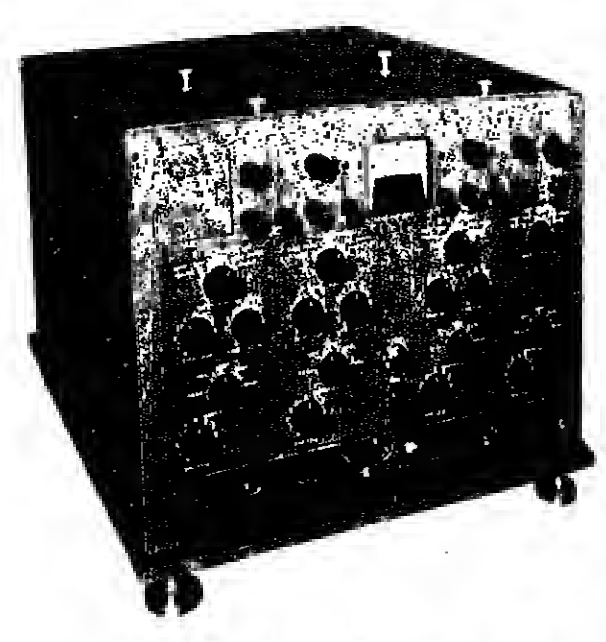

Fig. 29. Photographic recorder for direct optical recording of galvanometer traces on 35-mm film strips. The recorder could remain in a lighted area except when the film strips were being replaced.

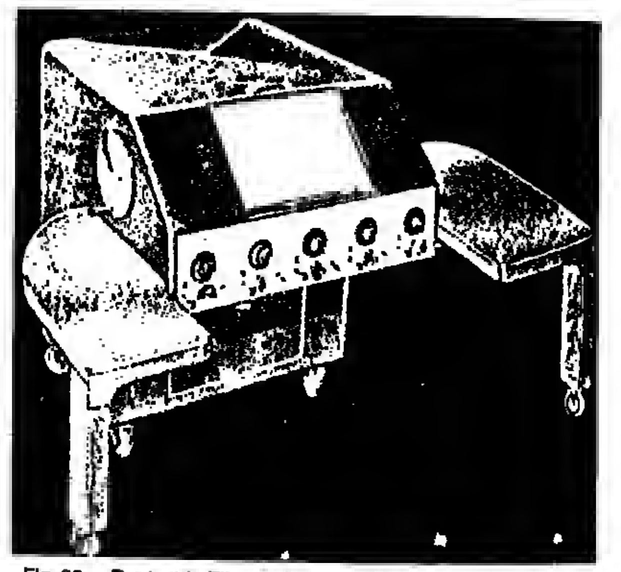

Fig. 30. Pentastrip Film Viewer, manufactured by American Instrument Company.

Early Photographic Records and Recorders

Early photographic seismological records were of two forms: sensitized paper and 35-mm film. The paper strips were about 30 cm wide and 97 cm long. Such strips were wrapped around a drum having a 90-cm circumference. As the drum rotated once every 15 min, a time scale of 1 mm/s was provided. On such a scale, microseisms show clearly when the system has good sensitivity. If the drum is translated along its axis 3 mm per revolution, a 24-hour record can be accommodated on the single paper strip.

The USC&GS recorders were designed to use 35-mm film on narrow drums having 90-cm circumferences. Single drums were only wide enough to accommodate one film strip, but several drums could be in one recorder. The photographic trace was usually much finer on the film than on the paper record. Conventionally, the drums rotated twice an hour, providing a time scale of 0.5 mm/s. The recorder drums were not enclosed, so the recorder was operated in a dark room. These recorders were equipped with galvanometers that were sufficiently sensitive to be driven directly from the seismometers.

A similar recorder, Geotech Model 1301A, was built in a light-tight case, by using a Benioff design. This recorder used 5-Hz galvanometers for direct connection to seismometers and a 20-Hz galvanometer to be driven from a radio time receiver output. The drums carried 35-mm film strips, just as in the USC&GS recorders. The drums were translated 0.795 mm per revolution to provide spacing of the recorded trace on successive revolutions. Time marks were made on each trace by an electromagnetic device which changed the angular position of a small mirror in the light beam, thereby causing the seismic trace to be deflected momentarily. Figure 29 shows this recorder, which was in service early in 1953.

Two such recorders were normally used, as follows: One recorder accepted the signals from four vertical-component seismometers spaced 1 km apart along a line. On this recorder, time marks appeared on the four channels, but the 20-Hz galvanometer providing radio time was omitted. The second recorder carried a signal trace summed from the four vertical-component seismometers, traces from the horizontal north-south component and the east-west component, and a radio time trace. Again, time marks appeared on all four traces, the radio time trace providing any necessary time correction.

Summation of *P* wave outputs of seismometers as much as 3 km apart usually will provide a signal-to-noise improvement, but confidence in the reality of a weak signal is enhanced by comparing individual seismometer outputs. Thus it became important to examine several seismic traces at once in the same time region. Also, optical projection to a larger image of each trace was desirable. Accordingly, a multiple-drum projector was designed and built in 1952 by the American Instrument Company of Silver Spring, Maryland. There were five drums in this projector, each carrying a film strip that was transilluminated by an incandescent lamp. The projected trace images, magnified 10 times, were focused onto a translucent screen in front of an operator's position, the images being brought close together on the screen for easy comparison. Each drum could be rotated and lighted independently, or all drums could be rotated together by a hand crank coupled by independent clutches to each drum. Figure 30 shows this device, called a Pentastrip Film Viewer.

Although this viewer was well designed for its purpose at the time, it remained obvious that there would be a great advantage if the traces from all seismometers in an installation could be recorded side-by-side on the same film strip. But 8 to 12 hours of a single trace filled one film strip, which could not be viewed until after development. There seemed to be no simple change that would lead to a better system. However, some unrelated events suggested an advance. 'Correlation' processes were much discussed in the literature at this time. Upon seeking a practical means of performing the correlation process on more than two signals, I asked NBS mathematician Chester Page to confirm some intuitive conclusions about sign (polarity)-matching multiple signals to establish this coherence or a statistical measure of the probability of signal existence in a noisy background. A theoretical study by Philip R. Karr [*Melton* and *Karr*, 1957] led to the submission of a project to Diamond Ordnance Fuze Laboratories (DOFL—associated with NBS) to devise a sign-coincidence correlator.

Jacob ('Jack') Rabinow accepted the project for DOFL in late 1951 but persuaded the Eastman Kodak Company (EK) to agree to build the necessary recorder. Ford Tuttle accepted the job for EK because it was in line with the company's basic interest. Thus EK agreed to devise a 16-mm film recorder that would process the film continuously for $10,000, and for an additional $560 to incorporate a viewer into the device ($580 may have been their cost for a standard 16-mm film viewer). In the proposed recorder, small argon lamps would flash to indicate instantaneous polarity agreement, and a high density of the resulting dots on the film would imply coherence of signals among several input channels.

A. W. Tyler and George Breslin began work on the experimental recorder in January 1952, and by March had an operating model in which three small rotating drums carried fluids up onto the sensitized surface of the film that had been exposed to light from the flashing argon lamps. The first drum applied developer solution, the second drum fixer solution, and the third drum wash water. A current of air then dried the film surface. In the completed recorder the film would proceed to the gate of a projector, be transilluminated by a lamp, and imaged through a projector lens onto a viewing screen. By the time this experimental device was operating, I had begun to see that incorporation of galvanometers with an associated optical system into this same recorder would provide for recording and viewing simultaneous signals. Even though there were no acceptable seismic amplifiers available in early 1952, I assumed that such amplifiers could be in service by the time a recorder could be designed for production. In March 1952, I provided Ford Tuttle with a memorandum and accompanying figure to suggest desirable features in the next model recorder, I showed two alternative forms of galvanometer traces, in addition to the dot pattern.

A few months later EK delivered a working model recorder on which eight galvanometer-produced traces were recorded along with the dot patterns from eight inputs, but they did not elect to carry forward the necessary engineering for production. The next contract went to American Instrument Company, which built an experimental model, but that company's management decided that continuation of recorder development would not be as profitable as manufacture of their other lines. Geotech was then given a contract for the necessary development and engineering for production. However, the dot pattern record was eliminated because experience showed there was insufficient advantage to be gained by the sign-coincidence correlation for detecting one or two cycles of a weak signal in noise.

A major optical problem with the EK recorder stemmed from its use of individual field lenses for each recording trace. These lenses concentrated the available light from the galvanometer mirrors, and they were a necessary part of the optical system in EK's opinion, but each field lens limited the excursion of the transmitted light beam to the edges of that lens. The result was to limit each film trace to a 'track,' thus preventing the trace from crossing one or more adjacent traces. This imposed a severe, probably unacceptable, limit on dynamic range. To increase light intensity in ways other than through use of a field lens, EK had proposed use of a special ribbon-filament lamp, the filament being imaged in place of a slit. I rejected this change because of future problems envisioned in supplying special lamps.

The individual most immediately concerned with further development and engineering was Jack W. McElwain of Geotech, although many other people and resources were available. The optical problem was solved by use of an 'opal glass' screen in place of the field lenses, plus further attention to optical details, including the galvanometer mirrors. A conventional automobile 12-V lamp (tail light) was eventually used, at reduced voltage, to increase lamp life dramatically. An incandescent lamp life varies inversely as about the 13th power of its applied voltage.

Further development of this recorder, dubbed 'Develocorder®' by Geotech, depended upon details too numerous to describe. One subsystem was the time and date imprint feature, which involved many trials and alterations but which was critically important for referencing purposes. A compromise here was acceptance of numbered days of the year rather than month and date. In an alternative arrangement, a cathode-ray oscillograph screen was imaged on moving film. Figure 31 outlines the functional components of this recorder. The first production models were in service in mid-1958. About 270 have been manufactured, and most of them are still in service.

Develocorders® have been manufactured in three versions: a 16-channel short-period, a 20-channel short-period, and a 20-channel long-period model, all looking essentially like in Figure 32. The Develocorder® that records a cathode-ray oscilloscope screen appears the same but is mounted on a cabinet which encloses the oscilloscope and its controls. The oscilloscope screen is horizontal, and it is photographed through a chimney in the cabinet top.

Although the Develocorder® provides for continuous inspection of seismograms within a short time after recording, the review and analysis of these records may require some hours. For this reason a film viewer, Figure 33, was designed and put in service in mid-1960. This viewer accommodates reels holding as much as 400 feet of film, although a standard Develocorder® is designed to accept 200-foot rolls. A projector produces a x20 image magnification on a viewing screen, and the film can be moved rapidly or slowly through the projector gate by a motor drive.

One other recorder, useful for instantaneous monitoring of seismograph operation, became available about 1954. This is the 'Helicorder®,' which developed from a very similar device used by Benioff. Benioff introduced the method of scribing a line on a paper covered with a white wax, the scriber having an electrically heated wire tip for the purpose. However, the Benioff recorders were usually in groups of three, the drums being on a long common shaft. When Jack Hamilton wanted to sell similar recorders to the Air Force, we told him that they would not be purchased unless they were modified for standard rack mounting. The final design was a rack-mounted single-drum recorder that could accommodate from one to three scribers and whose drum could be run at various speeds, dependent upon the gears chosen. Figure 34 shows this recorder. An associated amplifier provided adjustable voltage gain and a timing input circuit to make time marks by deflecting the scribe a controlled amount.

The Dry Film Recorder

There have been many investigations and attempts to eliminate the wet chemical processes of the Develocorder®, but none survived preliminary investigation until about 1972, when Burnard Kirkpatrick of Geotech was given support to devise a system around a '3M' (Minnesota Mining and Manufacturing) dry film process. Kirkpatrick and others created a recorder in which a laser beam burned off the emulsion from 16-mm 3M film selectively. The beam was gated on and off by an electrooptic (pockels cell) shutter while scanning across the film. This put a microscopic hole in the emulsion each time the electrooptic shutter allowed the beam to pass. The completed engineering prototype, Model 36100, Figure 35, provided all of the features of the Develocorder® and also accepted the output of a typewriter keyboard for record identification purposes. It was sold to the Air Force in 1974 but never carried into production because of the high costs ($100,000) of necessary documentation and a very uncertain commercial market. Technically, it appeared to be a satisfactory device.

Timing Systems

If we assume that compressive body waves (*P* waves) are to be used to locate the focus of an earthquake, we need to know the arrival times of waves from that event at four or more stations. Each time difference between two independent records of the event implies that it occurred along a surface of constant time differences, and the intersection of two such surfaces (minimum of three stations) with the earth's surface defines (in principle) two epicenters; the common intersection of three such surfaces (four stations) defines the focus, or hypocenter.

In order that any of these time differences between stations can be measured, and assuming no communication between stations, their clocks must carry the same time. Before 1950 a pendulum clock at a seismological observatory was equipped with electrical contacts that closed at programed intervals, the minimum interval being 1 min. These clocks were set closely to world time, and their rate was monitored consistently so as to know their error. In 1949, world time observatories were located at Greenwich, England; Paris, France; the U.S. Naval Observatory at Washington, D.C.; and the NBS radio station at Beltsville, Maryland. However, it was difficult to be assured that those observatories kept the same world time within, say, a tenth of a second. They made independent star-transit observations at intervals when weather permitted, but each observatory's zenith direction, if uncorrected, depended on the local gravity vertical. Also, they had to rely on pendulum-controlled clocks ('free-pendulum' Shortt clocks) for carrying the time between observations. Crystal-controlled clocks were still under development and were not trusted.

The Bell Telephone Laboratories were approached to see if they would undertake development of a timing system suited for use by Air Force stations. They declined, but recommended American Time Products (ATP), New York, N.Y., as a competent organization to devise a clock whose basic rate would be controlled by an electrically driven tuning fork. ATP had been building such fork-controlled devices for use in timing watch balance-wheel rates. Also, the broadcast stations kept accurate scheduling time with ATP-driven clocks.

Figure 36 shows the ATP programer designed for the Air Force. In this device, a 240 Hz electrically driven tuning fork in a temperature-controlled oven fed two cascaded multivibrator stages to deliver 60 Hz. A power amplifier provided about 50 W of 60 Hz at a nominal 115 V. Part of this power drove a synchronous clock motor. The motor drove a gear train to actuate switches by means of cams, and the switches were arranged to close a circuit on the following schedule: one 0.3-s pulse every 10 s except on the minute, one 0.5-s pulse every 5 min except on the hour and half hour, one 1.0-s pulse on the half hour, and two 1.0-s pulses, separated by 1 s, on the hour.

The remaining power output was available to drive recorder motors in the seismograph station.

To assure continuous timekeeping in the event of power or electronic failure, pendulum clocks were investigated. This

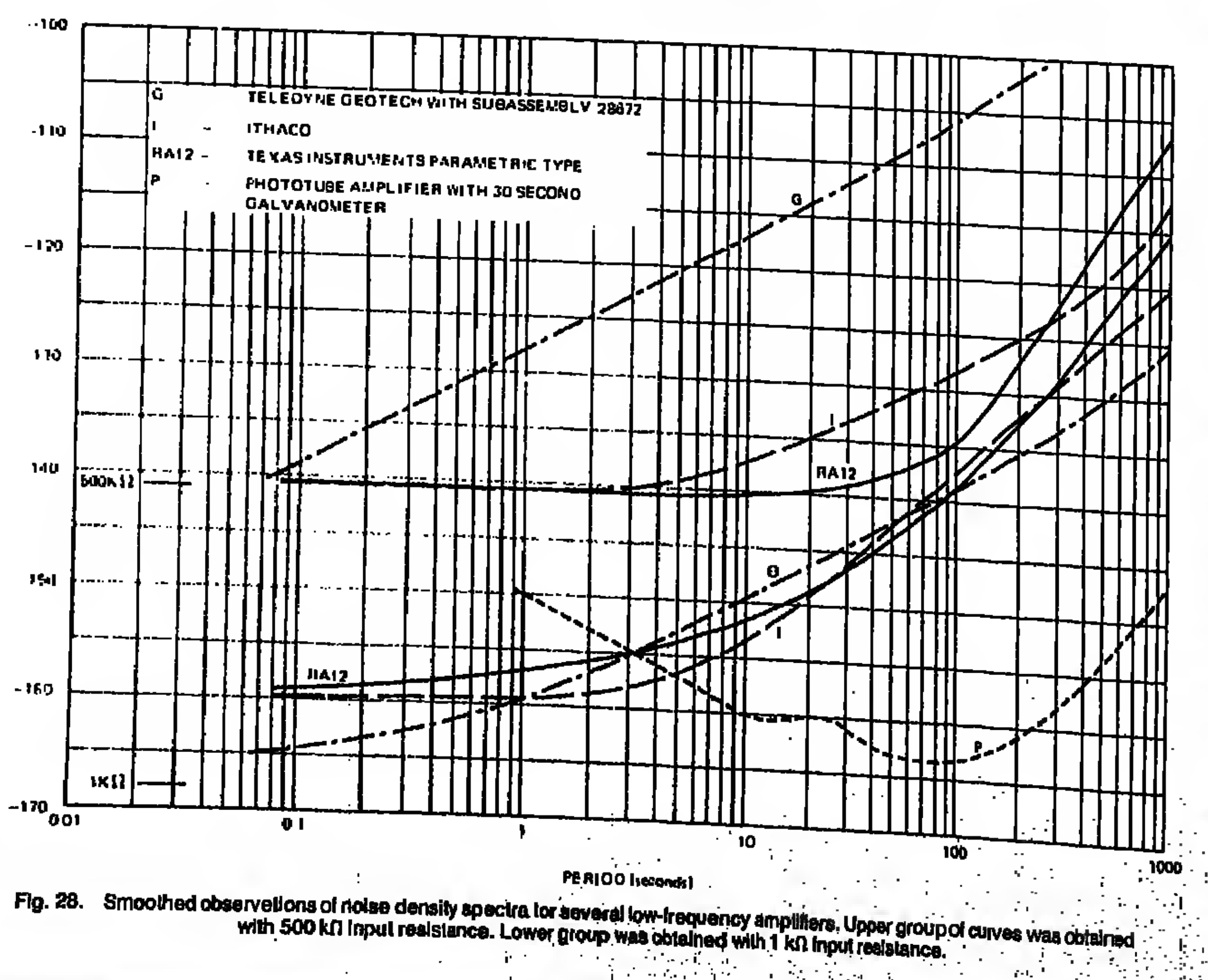

Fig. 28. Smoothed observations of noise density spectra for several low-frequency amplifiers. Upper group of curves was obtained with 500 kΩ input resistance. Lower group was obtained with 1 kΩ input resistance.

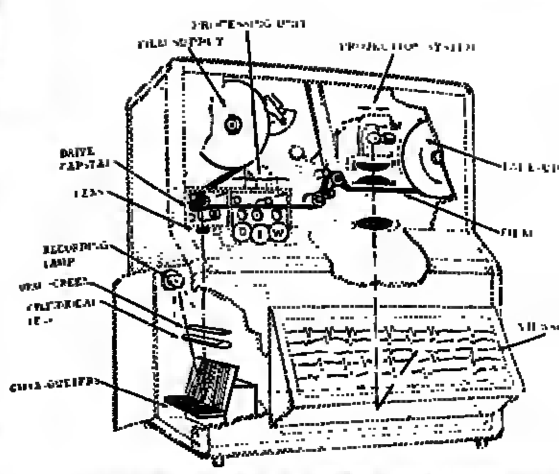

Fig. 31. Diagrammatic outline of Develocorder® functional components.

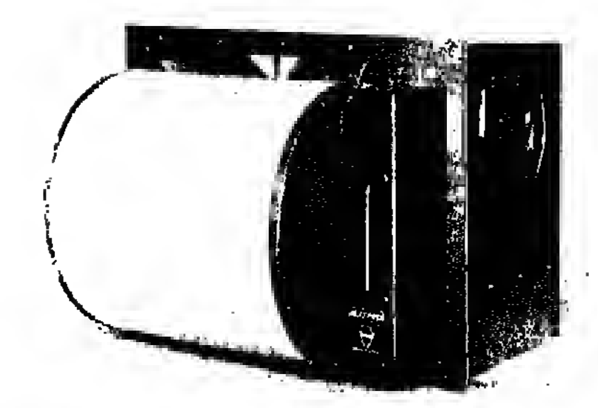

Fig. 33. Film viewer. This viewer accommodates unperforated 16-mm film and displays a x20 magnification of the photographic image.

Fig. 32. Develocorder® in (simulated) operation, showing illuminated record traces. The images appear 10 min after recording of short-period waves, 70 min in the case of long-period recordings. There are only minor differences in appearance of the several models.

Fig. 34. Hot stylus visible recorder. The paper used on this recorder has a black surface covered with white wax. An electrically heated stylus scribes a trace by melting the wax. Alternatively, a translucent paper can be used so that removing the wax provides a negative for photographic reproduction.

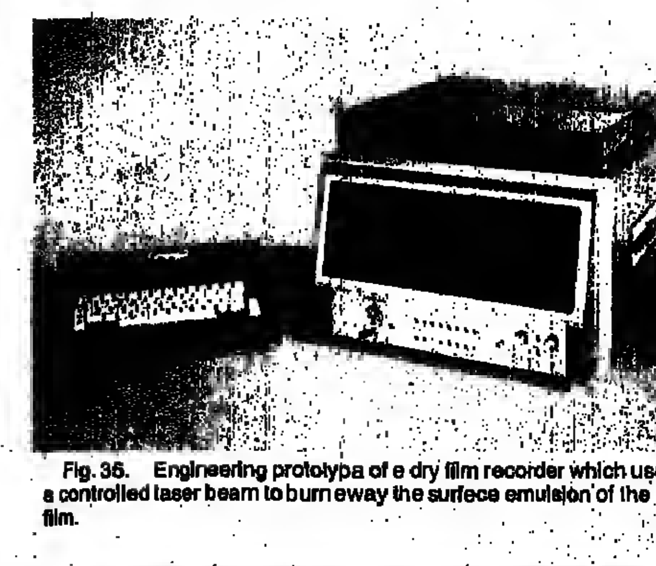

Fig. 35. Engineering prototype of a dry film recorder which uses a controlled laser beam to burn away the surface emulsion of the film.

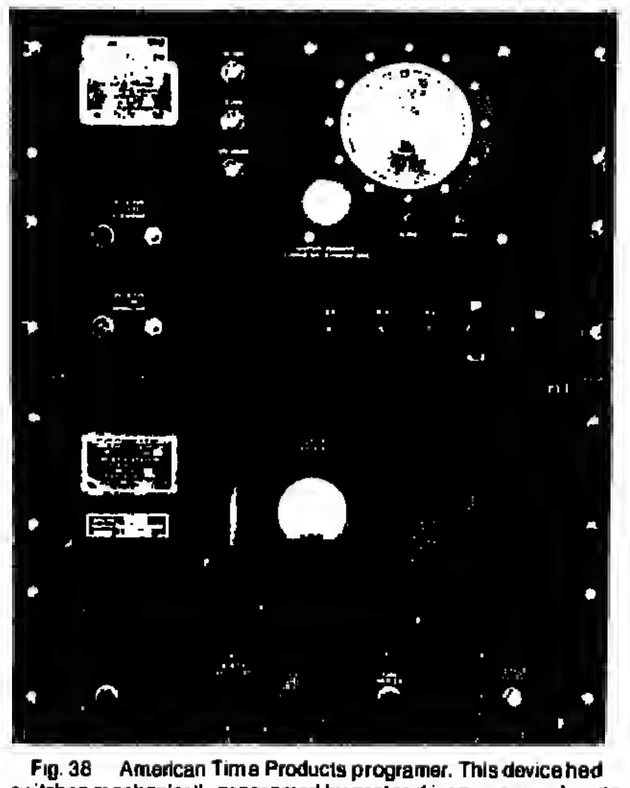

Fig. 38 American Time Products programer. This device had switches mechanically programed by motor-driven gears and cams to provide circuit closures at scheduled time intervals. The circuit closures actuated electrical elements in associated seismographic recorders to put time marks on their records.

resulted in the purchase and use of British-made Synchronome Clocks, to be driven from a separate battery supply. The escapement of this clock provides a contact closure every 30 s, which energizes an electromagnet to give the pendulum a slight push at the bottom of its swing. The pendulum then swings freely until the escapement initiates another electrical impulse. The time rate of this clock is good because its escapement requires very little energy—energy which would damp pendulum oscillations—and because very little energy is used to keep the pendulum swinging. (This clock is actually the slave portion of the two-pendulum Shortt clock used in many time observatories in the 1950's.)

In 1953 the crystal-controlled clock was reconsidered, and Texas Instruments designed a system, Model 100B, which is shown in Figure 37. To attain reliable operation of the crystal-frequency divider chain, only binary dividers were employed to convert the crystal frequency to the 60 Hz desired for operation of clocks and recorders. Unfortunately, this limited the choice of crystals to those whose frequency was a power of 2 multiple of 60 Hz, crystals which were not the standards in multiples of 10.

By the time this system was designed, experience had shown that either the NBS station at Boulder, Colorado, WWV, or WWVH, the NBS station in Hawaii, could be received at nearly all Air Force observatories at some time during any 24-hour period. Therefore, a means of accurate observation of an NBS time signal relative to the local crystal clock time was required. To accomplish this function, a neon lamp was mounted back of a slot in a disk which rotated once a second, the disk being geared so that the slit was at the top exactly on each second pulse of the clock. The neon lamp was triggered on by the WWV time signal on each (world time) second. Then by the relation of the light flash position to the top of the circle covering the disk, the error in fractions of a second could be observed.

Later, investigations disclosed that the crystal-frequency divider transistors were not driven well into saturation, so at higher ambient temperatures one or more stages might lock in an intermediate state, causing timing system failure. Also,

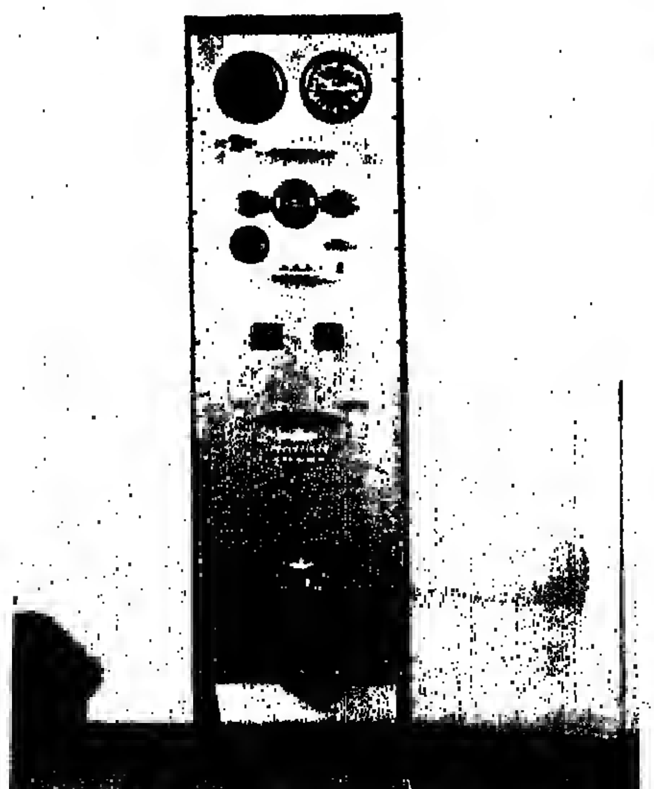

Fig. 37. Crystal-controlled timing system built by Texas Instruments. This system was designed for operation from the ac power line, requiring 325 W at 45 to 60 Hz.

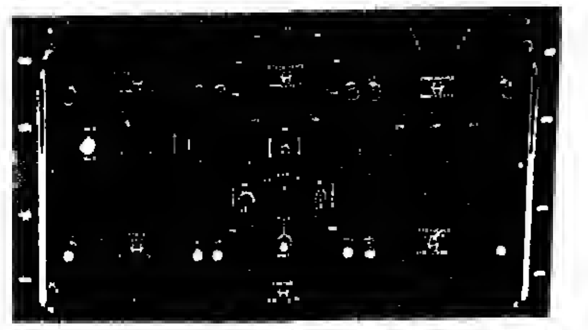

Fig. 38. Modular assembly timing system designed for operation from a storage battery supply, 22 to 28 V dc.

the 60-Hz output tubes overloaded because not all of the primary turns of the output transformer were used, and much of the plate current was required to saturate the core. The corrective action was to use all of the primary. An appropriate secondary tap then raised the output voltage considerably. A step-down transformer and a full-wave rectifier were connected to the output, and the resulting dc was introduced as a grid bias to an earlier stage in the amplifier, thereby lowering and stabilizing the power output voltage, also lowering the plate current of the output tubes. Installation of these 100B systems in air-conditioned areas stopped the erratic failures in the frequency divider.

The need for a semiportable timing system for use by temporary field observatories brought forth the next design, which was put in service in the latter part of 1958. A modular assembly was proposed by James R. Womack of Geotech, with the obvious advantage that a change of functions would not require complete redesign. A tuning fork-divider clock/programer that would deliver a simple sequence of time pulses was planned originally, but claims for a low-cost crystal oscillator with 10^{-7} precision and other desired functions resulted in a more sophisticated design. Figure 38 shows this Geotech Model 5400 system. The upper row of modules, from left to right, are (1) crystal oscillator with control to adjust frequency if necessary, (2) stroboscope to observe relation to WWV time signal to local clock setting, (3) clock and programer to deliver programed output pulses to recorder. The lower modules are (1) power amplifier to deliver precision 60 Hz for recorder drives, (2) input power (24-V dc) distribution and control module with speaker, (3) crystal-frequency divider chain. (The crystal frequency is 60 times the 9th power of 2, or 30,720 Hz, so nine binary counters comprise the frequency divider.) This timing system later became part of the World-Wide Seismograph System, Model 10700. The total network is now known as the Worldwide Standard Seismograph Network.

With the advent of magnetic tape recording, and the attendant necessity of automatic scanning to locate a specific time on the tape, another form of time code was required. Also, long-period recordings needed a somewhat different time mark output than that for short-period records. To satisfy such requirements and to take advantage of later technology, the Geotech Model 19000 system, shown in Figure 39, was

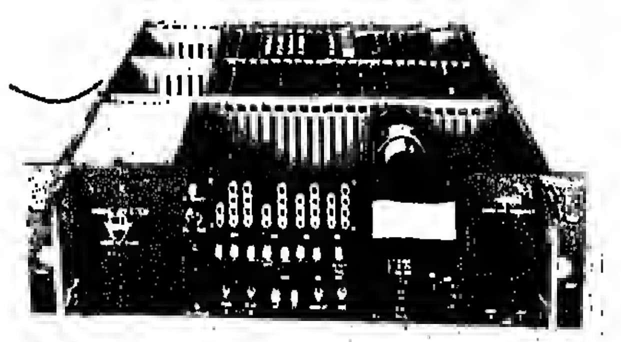

Fig. 39. Improved timing system designed to provide several forms of output codes, including one for magnetic tape recording and automatic scanning.

devised. Better crystal oscillators provided a drift rate of less than one part in 10^9. The function of comparing system time to WWV or WWVH was incorporated in an oscilloscope with three different sweep rates, and also provision was made to heterodyne the crystal oscillator frequency with the received radio signal. The magnetic tape time code conformed to VELA-UNIFORM* specifications. Finally, 100 V-A of frequency-regulated 60-Hz power was provided for driving recorders. These timing systems became available in 1964.

The Model 5400 and the Model 19000 timing systems were designed to operate from a storage battery supply, 22- to 28-V dc, the batteries normally being charged by (rectified) power from a 115-V ac power line. This avoided system outages caused by temporary ac power failure and reduced the importance of having a mechanical clock for backup. The battery supply provided both plus and minus 12 V, which permitted design flexibility in solid-state systems.

Conclusion

The period covered by this history was also the period during which scientific knowledge and engineering technology advanced greatly. At the beginning, little was known about earth noise, its source, or its variation with depth beneath the surface. Pendulum clocks were the most trusted means of timekeeping. Vacuum-tube amplifiers were inadequate at seismic frequencies. Solid-state devices were limited in application and power. Seismic signal transmission was limited to the vicinity of each seismometer. Multichannel recording of seismic arrays was impractical. Immediate observation of seismic records was limited to mechanical seismographs. Digitization of records for computer processing was slow and laborious. Magnetic tape recording was impossible without the required low-frequency amplifiers.

At the end of the period the data on earth noise had been collected and coordinated. Crystal or atomic clocks were available. Vacuum tubes were nearly obsolete, while solid-state devices had advanced in sophistication and power-handling capacity. The basic theory of seismometers is better understood and has permitted the design of smaller, more useful instruments. Multichannel records are available for quick inspection, and digitization can be near the signal source or elsewhere in the system. The seismologist now has at his disposal some tools which he could scarcely have foreseen, or even appreciated, in 1948. Technological advances after 1975 not covered in this history have altered many processes of handling large quantities of data, but I leave them for others to discuss when enough time will have passed to permit objective assessment of their impact on seismology.

Other than that, there is a growing appreciation of the fact that noise measurements in deep wells in some formations now show a marked decrease of noise with increase of frequency beyond 1 or 2 Hz. This is in a range suited to the use of crystal-pressure accelerometers, wherein the inertia of a mass in contact with the crystal provides an adequate output. Dynamic damping here will prevent crystal oscillation and eliminate loss damping thermal noise, and electronic amplifiers are more easily designed for these frequencies. The result may be sensing capabilities beyond those imagined today.

*The U.S. Government program to monitor underground nuclear explosions.

Acknowledgments

The attentive reader will realize that I have had immeasurable, unstinted assistance in my search for supporting documents, negatives, and unofficial notes. For this, and for use of the typing and reproduction facilities of Teledyne Geotech, I am indebted to Gordon W. Breland, the company president, and to members of his staff. Also, special thanks are due Dennis Racia of the organization, who saved in his personal files many obsolete items and discarded memoranda, making them available to me.

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News

Dallas Peck Selected for USGS

Volcanologist Dallas Peck has been chosen by the Reagan administration to be the next director of the United States Geological Survey (USGS). Peck, chief geologist of the USGS since 1977, is a past president of AGU's section on Volcanology, Geochemistry and Petrology. If the Senate approves Reagan's choice, Peck will become the 11th director of the USGS, succeeding H. William Menard, who resigned in January. Doyle G. Frederick, associate director, has been serving as acting director.

Dallas Peck is highly regarded throughout the Survey. His field studies include notable work in the Cascades of western Oregon, in the Sierra Nevada batholith, and at the Lava Lakes in Hawaii. He has been involved with geological projects in Alaska as well as with numerous studies in the U.S. related to geothermal and volcanic energy sources.

The Geological Survey will benefit from Peck's administrative abilities. He first joined the Survey as a field assistant during the period 1951–53, just after receiving his B.S. in geology from CalTech and while he was completing requirements for the M.S. He then went to Harvard for doctoral studies and rejoined the survey to finish his thesis. The thesis was completed in 1960, and he was awarded the Ph.D. degree. Between 1960 and 1977, Peck followed the customary USGS practice of rotation between field and administrative duties. It is often said that the USGS directors during that period considered his advice, counsel, and services indispensable. He had to fight for his terms in the field, away from Washington.

The USGS has been noted throughout its history for its professional excellence. It would appear that there will be no break in that tradition under Peck's direction.—*PMB*

Mission to Observe Oceans Proposed

Most serious of the obstacles to understanding ocean circulation is the 'absence of any widespread means for observing it,' according to the recent report of the Ocean Topography Experiment (TOPEX) Science Working Group. To overcome this hurdle, the panel recommends a 5-year satellite altimetry experiment to measure the ocean's topography. Aim of the experiment would be to yield a global view of ocean dynamics. A better estimate of the geoid—vital to many geophysicists—would result from TOPEX, the group said. A better understanding of ocean circulation would also aid commerce and shipping, fishing, national defense, and weather prediction. In addition, it could help to evaluate ocean disposal of radioactive wastes.

Oceanographers now rely on ships, buoys, and drifting floats to yield ocean data. These instruments, however, can only chart the ocean for a few months at a time in discrete regions. 'No existing method permits observation on the global scale that is required to measure and understand the ocean as an entity,' the panel reported. Satellite altimetry of the oceans has the 'demonstrated capacity' to observe global ocean circulation, the working group concluded.

Established last year by NASA's Environmental Observation Division, the TOPEX group was charged with assessing the usefulness of satellite measurements of ocean topography. Carl Wunsch of the Massachusetts Institute of Technology chaired the 15-member panel. The Jet Propulsion Laboratory was responsible for conducting the study.

The group recommended that NASA start a 5-year satellite altimetry experiment to measure ocean topography. These measurements would be integrated with subsurface data and models of the ocean's density field to determine the general circulation and variability of the ocean, according to the TOPEX report. Then, scientists could calculate the heat transported by the oceans and the interaction of currents with waves and sea ice. The ability to predict the circulation caused by wind movements also could be tested. The TOPEX group had hoped for initial funding in the fiscal 1983 budget, with launch of the satellite to follow in 1986, Wunsch told *Eos*. It's an unlikely candidate, though, for the fiscal 1983 budget with the present tightening of the fiscal belt, he added.

Why satellite altimetry? The working group emphasized the need for the accuracies obtainable with a TOPEX satellite. These accuracies, the working group said, have been demonstrated with Geos-3 and Seasat. In addition, altimetry does not depend on cloudless skies and good weather; it works under any conditions. Heavy rain may cause difficulty in data interpretation, however.

The working group also pointed to the data interpretation possible with satellite altimetry: 'The large-scale movement of water in the sea tends to manifest itself as an elevation change of the sea surface proportional to the strength of the surface currents. If the currents are time varying, then too is the surface elevation.' In addition, this sea surface elevation quantifies the surface pressure of the sea (not atmospheric pressure) directly related, by known equations of motion, to subsurface water movements.—*BTR*

Geophysics at Sea: Rising Fuel Costs

In the past year or two the costs of fuel for research vessels have seriously affected geophysical and oceanographic studies at sea. Many vessels have not left the dock during that period, others have been used sparsely, and research programs have suffered.

The National Science Foundation has considered new efficient vessels to replace the currently existing fleet. New propulsion systems are being considered, although for this decade, no large breakthroughs are expected in the efficiency of diesel engines.

Ten years ago, diesel bunker fuel sold for about 15¢ a gallon. In 1973 the price had tripled to about 45¢. In 1980 the price per gallon had risen to more than one dollar, about 700% increase over the pre-1973 prices! The fuel costs always were a large part of the operation budget of a research ship, so the increases have affected the entire oceanographic community. A small marine engine of approximately 400 horsepower, operating at 75% of its load capacity for a year's use in 1970 cost about $15,000. At a cost of $105,000 in 1980, the engine would be prohibitively costly. Many small to medium research vessels use a separate 1000-horsepower diesel engine for propulsion and for onboard electric power generation. Larger vessels use proportionally more horsepower, but with larger engines comes improved efficiency, a possible key to solving the fuel problem for the 1980's. The engines themselves will probably not improve in efficiency (20% improvement by the 1990's is optimistic), but it is possible that the larger vessels with larger engines will be used more than smaller vessels. The fact that more stations at sea, more instruments, and more project per cruise in large vessels will offer the only practical answer. Oceanographic research budgets are not expected to rise sufficiently to absorb the new costs.—*PMB*

Nation's Water Picture

The nation's water picture improved somewhat in the north central and northeastern United States during May, but below normal water resources conditions persist in the Southeast and parts of the Midwest, according to the U.S. Geological Survey.

USGS hydrologists said May streamflow averaged well below normal—within the lowest 25% of record—at half of the 162 key index stations reporting from across the country. These extreme low flows were reported in all or parts of 33 states and were concentrated in a wide band from Virginia west through Tennessee and south to Florida and Mississippi.

The persistent dry trend was also evident in the combined flow of the nation's 'Big Five' rivers—Mississippi, Columbia, St. Lawrence, Ohio, and Missouri—which averaged 981 billion gallons a day (bgd) during May, 12% below normal. Although combined flow of the Big Five now has averaged below normal for six straight months, flow has begun to show some improvement over past months. The Big Five rivers account for almost half of the stream runoff in the conterminous United States and provide a quick, useful check on the nation's water resources.

Highlights of May Water Conditions

Northeast. Streamflow conditions generally improved throughout the Northeast, with New Jersey and Maryland reporting strong improvement and flows that were above normal at several gaging stations. Some improvement was also noted in the Delaware River Basin.

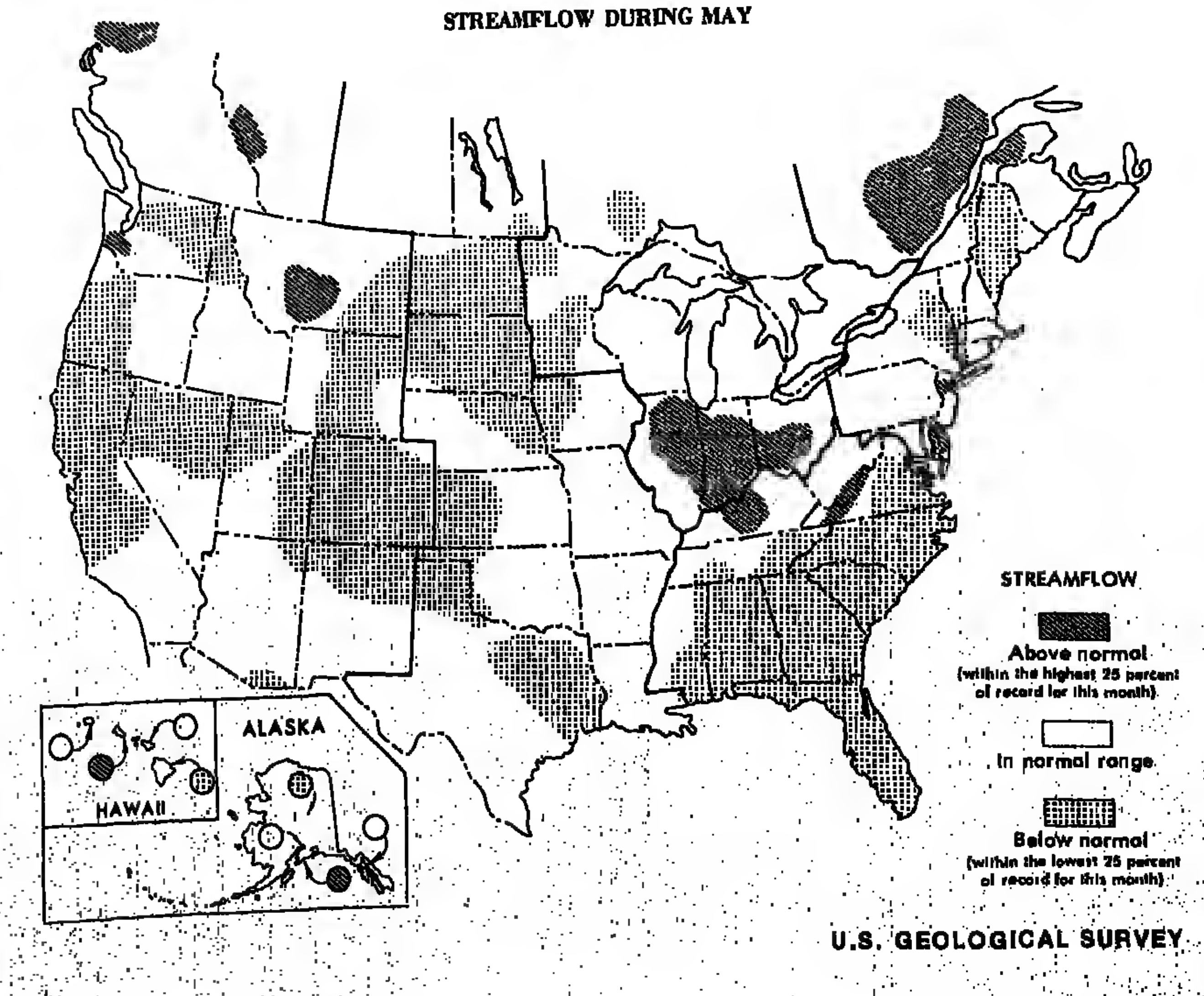
Southeast. All but three of the 32 index stations reporting from Virginia to Florida were in the lowest 25% of record during May. That is, 75% of the time flows have exceeded those reported during May. New monthly record low flows were established in Virginia, North Carolina, and Georgia. Groundwater levels in most states are below normal for this time of year and, in some areas, are reaching record low levels. Streamflow in North Carolina has been below normal for six straight months.

Great Lakes Region. Streamflow was generally in the normal range throughout the Great Lakes Region, although scattered pockets of low flow were reported in Minnesota, while parts of Ohio, Indiana, and Illinois reported above normal flows.

Midwest. Streamflow in much of the Midwest remains below normal, stretching from North Dakota south to Texas and into the Rocky Mountain states of Colorado, Wyoming, and Utah.

Far West. During May, 11 of the 24 gaging stations reporting from Washington, Oregon, Idaho, Nevada, California, and Arizona reported below normal flows, i.e., within the lowest 25% of record. Streamflow throughout California was below normal for the month, in response to a season of below normal precipitation.

STREAMFLOW DURING MAY



Postdoctoral Fellows: A Diminishing Supply

Highlighting the modern concept of what used to be positions of status are descriptive terms such as the 'perennial postdoc.' The research scientists with new Ph.D. degrees in hand that were awarded postdoctoral fellowships have been likened to 'planes . . . stacked in a holding pattern' (E. M. Looper, *Acad. News Rep.*, *31*, p. 3, 1981). In the fields of physics, chemistry, and biology a situation of 'extended appointments' for postdocs still exists because of a lack of full-time positions at the Ph.D. level.

The situation in the earth sciences contrasts sharply. Recent hiring patterns by petroleum and mining companies and by the federal government have followed a quickened pace. Geoscientists at the bachelors' and masters' levels are going directly into industry. Graduates in earth science with Ph.D. degrees are accepting research positions in industrial and government laboratories and thus are bypassing the postdoctoral experience. As a consequence, the number of graduate students and postdocs in earth science academic departments has fallen sharply over the past year.

A desirable balance between job offers and available personnel seems to have been lacking. When the total number of postdocs expanded in the 1970's, cutbacks in the space program produced uncertainties in the job market so that postdoctoral appointments, normally 1–2 years, were extended for an additional year or two. Postdocs moved from laboratory to laboratory, resulting in a good deal of frustration; feelings ranged from disappointment to bitterness as postdocs saw the number of permanent job opportunities decrease.

Now the problem is reversed. The award of a postdoctoral fellowship used to be considered prestigious, an unusual opportunity to gain experience and to do some serious research under the auspices of a famous mentor. Aside from the instances where postdocs have been used as 'cheap labor for established investigators' who were trying to meet grant or contract deadlines, the postdoctoral fellowship experience is still considered valuable and essential. The memories of recent bitterness coupled with attractive offers in petroleum and resources have prompted many Ph.D. holders to bypass the postdoc.

If past employment cycles persist, it may not be long before the job market tightens again, producing another increase in postdocs. It is noted, however, that even 'the postdocs caught in the holding pattern are filling vital roles in research.' (*Postdoctoral Appointments and Disappointments*, 429 pp., National Academy Press, Washington, D.C., 1981.) All things considered, the postdoctoral experience is highly beneficial to the Ph.D. holder who is headed for a career in research or in teaching at a research-oriented university. The contributions to science of the postdoc are considered valuable enough that the National Academy of Sciences' Commission on Human Resources now recommends that postdoctoral stipends be raised to be comparable to the average starting salary of an assistant professor. (The average stipend now is 40% less.)—*PMB*

Political Action Committee for Scientists

Spurred by budget proposals that could severely reduce science funding (*Eos*, March 24, March 3, February 10), seven scientists currently serving as Congressional Science or State Department Fellows recently founded a political action committee (PAC) for scientists. The Science and Technology Political Action Committee (SCITEC-PAC) aims to make scientists more politically aware and better informed about potential legislative actions that affect research. It will also serve to 'establish a political presence' with respect to science, said Donald Stein, SCITEC-PAC's chairman.

The organization is not a lobbying group, explained Stein, professor of neurology and psychology at Clark University and the University of Massachusetts Medical Center. 'Lobbyists seek to influence officials by presenting information to them,' he said, 'while a PAC tries to influence the outcome of elections through campaign contributions of money, time, and effort in behalf of candidates that share similar goals and aspirations.' In other words, the PAC will be a vehicle for promoting candidates for federal office who advocate strong support for scientific research and training. In addition, the PAC will develop and study science policy and budget issues and will attempt to stimulate government and private sector interest in these issues.

Scientists are traditionally reluctant to think about political activity as a method for furthering their cause, noted David Garin, SCITEC-PAC treasurer. Nobody ever thinks of scientists as an organized body because they never have been one, Stein added. Scientists can no longer sit back and watch the continuing erosion of federal support of science, he said. Scientists must make their needs known to Congress or else have their passiveness misinterpreted as a lack of concern, Stein said.

The PAC will not compete with scientific societies and their lobby groups, Garin and Stein emphasized. A nonprofit and nonpartisan organization, SCITEC-PAC will not take stands on issues, they said, but will apprise scientists of legislation that affects them.

To start this effort, the organizing committee opened an office at 305 Massachusetts Avenue, N.E., in Washington, D.C. They also are mounting a small fund-raising campaign this summer, to be followed by a larger direct-mail campaign early this fall. Stein says he hopes the organization will have gathered enough momentum to have an impact on the 1982 federal elections.—*BTR*

Langley Medal Awarded

Robert Thomas Jones, senior scientist at the Ames Research Center, Mountain View, Calif., was awarded the distinguished Langley Medal by the Smithsonian Institution for his 'extensive contributions in theoretical aerodynamics, particularly with regard to development of the swept wing, supersonic area rule and, more recently, the oblique wing.' Jones is an internationally acclaimed expert on aerodynamics, optics, and biomechanics as well as an applied mathematician, astronomer, inventor, author, and violin maker.

The Langley award has been given to just 18 recipients since it was established 73 years ago. Past recipients include Wilbur and Orville Wright, Charles Lindbergh, and Richard Byrd. Named for Samuel Pierpont Langley, aeronautical pioneer and third secretary of the Smithsonian, the medal honors 'especially meritorious investigations in the field of aerospace science.'

Jones discovered the theory of the "simple sweepback," one of the most important discoveries in aerodynamics (swept wings are seen on most jet aircraft today). Jones' 1944 discovery of the sweepback theory was not accepted by most scientists at the time, but NACA (later to become NASA) began experiments to test the theory. For his discovery of the swept effect slender wing theory and other contributions, Jones was given the Sylvanus Albert Reed Award by the Institute of the Aeronautical Sciences in 1946. That same year, he came to work for Ames Research Center.

In 1973, Jones was elected to the National Academy of Engineering and the American Academy of Arts and Sciences. He was honored in 1978 with a cash award from NASA's Inventions and Contributions Board and received the Prandtl Ring Award in 1978 from the German aeronautics Society (Deutsche Gesellschaft fur Luft und Raumfahrt), considered the highest honor in the field of fluid dynamics.

A Fellow of the American Institute of Aeronautics and Astronautics, Jones was chosen as an honorary fellow in 1979. In 1981 he was elected to the National Academy of Sciences.

Earlier this year, Jones was presented the President's Award for Distinguished Federal Civilian Service, in honor of the many contributions of his 40-year government career.—*PMB*

Reagan Names New Science Advisor

On May 19th the White House announced that Los Alamos Scientific Laboratory (LASL) physicist George Keyworth had been chosen for the position of science advisor to President Reagan. Evidently, Keyworth was selected after several other candidates, mostly from industry, had been eliminated from the running. The position of science advisor to President Reagan has been controversial. White House staff memoranda released over the past few months gave hints of the Administration's not wanting to fill the post vacated by geophysicist Frank Press. The 'corporate board structure' planned for the new administration simply did not have a logical place for a scientist with access to the President. After widespread outcries from the scientific community, the decision to eliminate the post of science advisor was reversed, followed by a quick search for a suitable candidate.

There are several new slants to the appointment. First, the decision to fill the post was critical. The science advisor heads up the Office of Science and Technology Policy (OSTP), which initially was to be transferred out of its high-level position at the White House. The exact relationship of the OSTP to the new administration structure remains unclear at this time, but it has been stated that the advisor will have the President's ear and will be involved in the budgeting process at the Office of Management and Budget.

Apparently, the Administration wanted an advisor with knowledge of the defense establishment. Candidates from the corporate world with sufficient stature for the position simply had too large a salary discrepancy (about a factor of 10 difference in salary between industry and government at this level). Keyworth, on the other hand, was supported strongly by Edward Teller and Harold Agnew, former director of Los Alamos, both 'well known for their hawkish views.' (*Science*, May 22, 1981, p. 903).

George Keyworth, B.S. Yale 1963, Ph.D. Duke 1968, age 41, is currently director of the Physics Division at LASL. He is not well known for his research and is not well known in Washington. He has the reputation, however, of being a very capable scientist with a flair for administration. In part the reason for his relative obscurity within the science community is related to the nature of his classified work at Los Alamos. Although he comes from 'outside of the traditional ranks,' Keyworth's credentials appear to be more than adequate for the present requirements of the post of science advisor.—*PMB*

New Publications

Remote Sensing in Geology

B. S. Siegel and A. R. Gillespie, John Wiley, New York, xi + 702 pp., 1980, $42.50.

Reviewed by Mark Settle

Geologists have traditionally employed a wide variety of 'remote sensing' techniques to obtain insight into the structure and lithology of crustal materials. Seismic methods, for example, are used to infer the configuration and physical properties of subsurface rock units through the analysis of acoustic wave measurements performed at or near the earth's surface. In recent years, however, the term remote sensing has come to be used in a more restrictive sense, to refer to the measurement of electromagnetic radiation that is reflected or emitted from the earth's surface. In this context, geological remote sensing is a relatively new and rapidly evolving field within the earth and planetary sciences. It is highly interdisciplinary in nature, involving individuals with backgrounds in various aspects of geology, geophysics, geochemistry, mathematics, engineering, and computer science.

Remote Sensing in Geology is one of a number of books that describe the basic principles, current methodology, and past accomplishments of geological remote sensing methods. The stated purpose of the book is to provide students in geology with 'a complete introduction to most of the aspects of remote sensing.' It takes a certain amount of bravery to devote one's time to the preparation of an introductory text on an emerging, multidisciplinary, scientific field, but several factors suggest that Siegel and Gillespie will be rewarded for their effort. *Remote Sensing in Geology* has been released at a time when interest in remote sensing methods is increasing, as evidenced by the inclusion of remote sensing courses in college curricula and expanding utilization of space-acquired data in geological studies. Furthermore, the collection of new and different types of data by currently planned sensor systems is likely to accelerate interest in geological remote sensing in the future.

Remote Sensing in Geology can be subdivided into two halves. The first half describes how remote sensing measurements are made and how the data collected by these measurement techniques is reduced and analyzed. The second half of the book describes past applications of remote sensing methods to geologic mapping, mineral exploration, glacial and geomorphic studies, engineering and environmental geology, and planetary exploration. The book was written by a group of highly qualified researchers with recognized expertise in different aspects of geological remote sensing. Each chapter within the book was prepared by an individual member of this group, in his or her area of specialization. This results in a somewhat uneven style of presentation. However, the chapters are organized in a logical fashion and the editors have diligently avoided any duplication of effort.

The book provides a comprehensive introduction to past research results and current measurement capabilities in geological remote sensing. However, it would be a mistake to view *Remote Sensing in Geology* as a self-contained text. In my opinion, the book would need to be supplemented with more specialized literature and more detailed case study examples of successful remote sensing projects to be used as an instructional text. The book lends itself to this type of use, in that each chapter contains an excellent bibliography of key references, and all of the images employed as illustrations are carefully documented.

Individuals involved in geological remote sensing may quibble with the emphasis or style of presentation in certain sections. I personally felt that thermal infrared and microwave imaging techniques should have received greater emphasis in the second half of the book. In addition, it seemed to me that several chapters in the second half devoted too much space to describing the geological characteristics of the earth's crust at the expense of describing how remote sensing techniques can be used to study these characteristics. It is quite conceivable, however, that someone with a background in engineering or computer science would have a very different reaction.

In an overall sense, *Remote Sensing in Geology* attains its stated goal. The editors and the authors are to be commended for preparing a comprehensive summarization of the current state-of-the-art within a rapidly maturing, interdisciplinary field. *Remote Sensing in Geology* is potentially useful for students, instructors, and researchers, and its audience is likely to grow throughout the 1980's.

Mark Settle is with the Office of Space and Terrestrial Applications, NASA Headquarters, Washington, D.C.

The Science and Wonders of the Atmosphere

S. D. Gedzelman, John Wiley, New York, xiv + 535 pp., 1980, $19.95.

Reviewed by Raymond C. Staley

Stanley Gedzelman and his associates at John Wiley have given us an attractive and scientifically satisfying introductory college survey text. The book is planned for students with no science or mathematics beyond that ordinarily required in junior high or middle school. Indeed, most of the text can be studied and understood satisfactorily by any ninth grade student who enjoys reading and who has some aptitude for science and mathematics. Every physical law introduced is explained, often with an accompanying historical background, and a worked-out numerical application is given. The book contains 48 numerical examples, along with about 75 similar problems to be solved by the reader. (These 75 problems are part of nearly 500 end-of-chapter questions spaced throughout the text. Hints to answers are given in a section at the back of the book.) Some college students using this text may complain that it is, at times, condescending, especially in these examples. Gedzelman has reason for introducing and emphasizing these examples and problems. He wants to overcome the fear so many students have of word problems and equations: '. . . I have found that despite the tearing of hair and gnashing of teeth among my nonscience students the first time they see me put an equation on the blackboard each semester, they inevitably perform (well) . . . and a few even revel in their new-found mathematical talent.' One of Gedzelman's first numerical examples shows how Eratosthenes estimated the earth's circumference, using the summer solstice position of the sun at Aswan and Alexandria in the noon sky. Gedzelman gives the historical picture and problem in three brief paragraphs; he then states the problem in sentence form, next in equation form, and finally gives a numerical solution in metric units. Most examples include a careful word statement, a statement in algebraic equation form, and a numerical solution. (In my opinion some examples could be improved by using only SI units and by more emphasis on dimensions and units. In examples 5.1 and 5.5 the millibar is mixed with SI units and unexplained dimensional conversion factors to give answers in SI units.)

Gedzelman strives to catch and hold the reader's interest with three introductory chapters on the wonders of the atmosphere such as optical phenomena and extreme and disastrous weather events. In his introduction he also uses the reader's assumed familiarity with TV weather broadcasts to initiate and support the study of surface weather charts.

The five chapters which follow contain very brief but probably adequate glances at the solar system and the atomic and molecular nature of the earth's entire atmosphere and introduce the concepts of pressure, energy, temperature and heat transfer. Chapters 8–14 move the reader rapidly through the heat budget of the earth, the hydrologic cycle and hydrometeors, including sections on thermodynamic diagrams, atmospheric stability and cloud physics, as well as descriptive sections on air pollution and agricultural meteorology. Chapters 15 and 16 explain how the earth's wind systems are driven and present climatological pictures of the wind distribution. Chapters 17 and 18 bring us back to the surface weather chart and introduce the 500 mbar chart. Chapters 19 and 20 look at local winds and storms, and Chapter 21 takes a brief glance at present-day forecasting methods. The remaining four chapters give a picture of the world's climates now and in the past, concluding with a brief look at the way weather and climate have affected land forms, human health and history, and (not least of all) the arts: literature, drama, and painting.

The text is obviously too long for the usual one semester or one quarter course. Gedzelman regards many sections as alternate and optional material. The instructor building a course on this textbook must select from it very carefully to construct the sort of one-term course desired. The book will serve best the instructor who has strong training in meteorology. (Contrary to Gedzelman's remark on p. 8, the text will not produce a reader who is '. . . almost a professional meteorologist by the end of the book.')

The text is attractive with large, clear neatly printed double column pages. Useful tables and well-drawn figures abound. The publisher has used two colors in printing the text material, black and maroon. This is fine for most people, but a total loss for the color-blind reader. It would have helped in many figures if red lines had been dashed and if red shading could have been stippled. In the numbered bibliography, advanced textbooks and sources are numbered in red. My color-blind colleague tells me he cannot distinguish the red from the black numbers (asterisks would have done the job).

I have not taught using this text, but I have discussed it with lecturers and teaching assistants who have used it. Lecturers are enthusiastic, while teacher assistants have mixed feelings, mainly because of what they see as the aforementioned condescending attitude of the author. I do not object to this, but I am annoyed in a few places by what I call 'cutesie' illustrations (especially the misleading Figure 1.5 which shows cartoon pedestrians feeling the earth's Coriolis force). Another fault (common to most such texts) is the omission of Alaska, Hawaii, Canada, Puerto Rico, and adjacent oceans from most weather charts and most synoptic discussion.

The text contains an excellent 12-page glossary of over 600 items. The 11-page index is detailed and very helpful.

An instructor using this text will probably want to add more numerical problems for homework drill. The text problems and questions should be read and checked before assignment. Gedzelman sometimes plays games with the problems (for example, problem 10.10 intentionally asks an impossible question). The instructor should be aware of this before writing a note to the author or publisher.

If you are a meteorologist teaching a course where this might be the text, I urge you to request an examination copy from the publisher and give it serious consideration. I think you would enjoy using it.

Raymond C. Staley is Visiting Scholar, Department of Atmospheric Sciences, University of Washington, Seattle, Washington.

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Research Faculty Positions in Physical Oceanography. The Department of Oceanography of the University of Washington invites applications for research faculty positions in physical oceanography. Applicants should have a strong experimental or theoretical background and must have a capability of developing a funded research program and teaching graduate level courses. Level of appointment will depend on the qualifications of the candidate.

The Department has a broad spectrum of on-going activities, operates three research vessels, and has strong interactions with other units in the University, such as the Applied Physics Laboratory and the Department of Atmospheric Sciences.

Applications with supporting data and four letters of reference should be sent to: Chairperson, Recruitment Committee, Department of Oceanography WB-10, University of Washington, Seattle, WA 98195.

The University of Washington is an equal opportunity/affirmative action employer.

Research Position/Space Plasma Physics. Applications are invited for two possible research positions in the Department of Space Physics and Astronomy, Rice University.

One position involves work on a computer code for simulating the large-scale dynamics of the earth's ionosphere and magnetosphere, including computer simulation of specific events and comparison with ground and satellite data. Preference will be given to applicants having experience with space or laboratory plasma physics, and with large computations.

The second possible position involves analysis of data from Atmospheric Explorer and Dynamics Explorer spacecraft. Preference will be given to applicants having experience with space plasmas and with reduction of spacecraft data.

Title and salary for either position will be arranged, depending on experience. Please send resume and bibliography to R. A. Wolf or P. H. Reiff, Department of Space Physics and Astronomy, Rice University, Houston, TX 77001.

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Meteorologist/Remote Sensing. Immediate opening for candidate with a PhD in Meteorology with post graduate research experience and interest in Remote Sensing.

Send resumes to: Melba Houston, Technical Recruiter, Systems and Applied Sciences Corporation, 6811 Kenilworth Avenue, Riverdale, Maryland 20840.

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Research Assistant. A position is immediately available for a person in the International Ground Water Modeling Center of the Holcomb Research Institute, Butler University, Indianapolis, Indiana. Successful applicant will have a hydrological background, preferably in ground water, and should have a Master of Science degree. The person must be acquainted with modeling principles, have a working knowledge of FORTRAN IV, experience in computer use, and should be able to communicate and work with a variety of individuals and institutions, both from the United States and abroad.

Primary duties of the position are to assist the Principal Investigator in updating the data base of the Model Annotation Retrieval System (MARS), and in screening and testing acquired models. Incumbent will also be responsible for entering and retrieving model annotations in, or from, the MARS data base. This person will insure the technical content of the ground water modeling newsletter and write technical reports in cooperation with other project members. Other technical and organizational duties will be assigned by the Principal Investigator.

Persons interested in applying for the position should send resumes by July 7, 1981 to:
Darrell R. Fishel
Business Manager
Holcomb Research Institute
Butler University
Indianapolis, Indiana 46208

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Research Associate. Position available July 1 for new Ph.D. scientist in climatology-glaciology. Work involves research in ice-climate synoptic interactions based on analysis of satellite imagery and digital data (Nimbus and DMSP systems) of climatological and cryospheric parameters using multivariate statistical techniques. Research is performed in a cooperative university-government laboratory employing scientists engaged in interdisciplinary work related to the environment. Position requires experience in analysis and display of remote sensing data and in data processing, demonstrated ability to write scientific reports, background of glaciological-meteorological field research in polar areas; experience in interpretation of snow cover, sea ice, and cloud conditions from visible, IR, and ESMR microwave imagery and digital data; experience with multivariate statistical analysis techniques, especially as applied to meteorological or related data; experience in FORTRAN programming in a CDC Kronos or NOS operating environment; and research experience in synoptic climatology and ice-climate interactions.

Salary approximately $17,000 per year. Applicants should contact the Colorado Job Service, 1701 33rd Street, Boulder, Colorado 80303, telephone (303) 443-6300, and refer to job order number 2217769, for referral to the employer, which is an equal opportunity affirmative action employer.

Temporary Staff Positions in Isotope and Trace Element Geochemistry. The research program of the new Geochemistry Division at the Max-Planck-Institute for Chemistry in Mainz is oriented toward the geochemical structure and development of the earth's mantle. Our facilities include a new Varian MAT 261 automated solid source mass spectrometer (in addition to older instruments) for isotopic analysis of Nd, Sr, and Pb.

Available at the Institute are also: electron microprobe, ion microprobe, INAA, XRF, spark source MS, and piston-cylinder apparatus. Applications are invited for geochemists with experience in isotope geology and petrologists with experimental experience in trace element partitioning. Appointments are normally made for two years, but a one year extension is possible.

Applications should be sent to A. W. Hofmann, Direktor Abteilung Geochemie, Max-Planck-Institut fur Chemie, Postfach 3060, 6500 Mainz, F.R. Germany.

Professor of Space Physics. The Institute of Geophysics and Planetary Physics of UCLA invites applications for an academic ladder faculty position in the field of space physics. The appointment is expected to be made at the level of professor. Applicants should have well established records in research in the area of fields and particles in space, and will be expected to conduct vigorous research programs in space plasma physics. Responses should include a resume of education, professional experience, and published research. Send replies to L. Knopoff, Associate Director, Institute of Geophysics & Planetary Physics, UCLA, Los Angeles, CA 90024.

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Physical Oceanographer/ Geophysical Fluid Dynamicist

Areté Associates, a growing research firm, located in Southern California, engaged in theoretical and empirical physical oceanography, is offering permanent, full-time positions. Candidates require Ph.D. (or equivalent experience) in physical oceanography or geophysical fluid dynamics. Salaries are competitive and negotiable, based on qualifications. Areté offers a fringe benefit package of superior quality. Qualified candidates should send résumé, salary history, and list of professional references to:

Personnel Administrator
Areté Associates
P.O. Box 350
Encino, CA 91316

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Research Coordinator
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Savannah, GA.

Skidaway Institute of Oceanography is seeking person with an oceanographic, meteorological or engineering background to join a research team investigating physical oceanographic processes on the continental shelf. This person must operate and maintain a remote oceanographic data acquisition system and must have experience with digital equipment and the processing of data originating from such equipment. He or she will be responsible for checking and calibrating sensors on a scheduled basis, for data editing and for data analysis.

Applicants should have an M.S. degree in a related field or have the equivalent in training and experience. Knowledge of time series analysis procedures and techniques, computer programming, and technical report writing are necessary skills. Independent research and publication of results will be encouraged.

Starting Salary: $16,600-$20,000 depending upon previous experience and qualifications. Send résumé including three references to: Dr. Jack Blanton, Skidaway Institute of Oceanography, P.O. Box 13687, Savannah, GA 31406. Phone (912) 356-2457/2453.

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Sedimentologist or Sedimentary Petrologist/University of California, Santa Barbara. (Correction) Applications are invited for a tenure track appointment in soft rock geology to be filled in 1981–82. Rank dependent on qualifications and experience but preference will be given to the assistant professor level. Applicant should normally have a Ph.D. and strong field-orientation and quantitative background. The candidate will be expected to develop a strong research program in sedimentation. The candidate will also be expected to teach at both undergraduate and graduate levels and interact with students and faculty of the department, particularly in the general areas of diagenesis, volcanic processes, paleomagnetics, as well as field geology. Additional duties may include teaching physical geology and summer field geology.

Please send resume, other documentation of abilities, and four letters of recommendation by September 30, 1981 to Dr. Arthur G. Sylvester, Chairman, Department of Geological Sciences, University of California, Santa Barbara, CA 93106. Telephone (805) 961-3156.

The University of California is an affirmative action/equal opportunity employer.

Geophysical Oceanography Postdoctoral Research Associate. The Department of Oceanography, University of Washington, is seeking qualified candidates for a Post-doctoral Research Associate position, available January 1982, to carry out research on interpretation of marine refraction data. A strong background in elastic wave propagation, inverse theory (including linear programming), and modern refraction data processing will be most helpful, as will an acquaintance with petrologic theories of oceanic lithosphere composition. Appointments are for one year, possibly extended for a second year. Send curriculum vitae and a list of four references to: Chairperson, Faculty Recruitment Committee, Department of Oceanography WB-10, University of Washington, Seattle, WA 98195.

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Scientist. Immediate opening for Scientist with experience in Lidar Analysis Techniques and Optics. Familiarity with Laser and Optics Instrumentation a plus. Candidate must possess a PhD in Atmospheric Science/Optics/Physics.

Send resumes to: Melba Houston, Technical Recruiter, Systems and Applied Sciences Corporation, 6811 Kenilworth Avenue, Riverdale, Maryland 20840.

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Postdoctoral Position in Geochemistry/Cosmochemistry, University of Arizona. Applications are invited for a postdoctoral research associateship in the Lunar and Planetary Laboratory at the University of Arizona. The associate will collaborate with Dr. William V. Boynton in ongoing investigations of the refractory inclusions in carbonaceous chondrites. The selected applicant will have major responsibilities to conduct mineralogical investigations to supplement existing neutron activation analysis studies. Experience with an electron microprobe is essential; experience with neutron activation is desirable. Facilities include a fully automated SEM/microprobe, numerous gamma-ray detectors including a Compton-suppression spectrometer, several computers and a TRIGA reactor.

Applications, accompanied by a resume, statement of research interests, and complete bibliography, should be sent to Dr. William V. Boynton, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721. Letters of recommendation, directed as above, should be requested from at least three persons who are well acquainted with the applicant's accomplishments and potential. To receive full consideration, application materials should be received by August 31, 1981.

The University of Arizona is an equal opportunity/affirmative action employer.

Faculty Position/Geophysics. The Department of Geological Sciences at the University of Texas at El Paso has an opening in geophysics which can be filled at either the assistant or associate professor level. The emphasis will be on obtaining a quality individual regardless of specialty. However, candidates who would complement existing programs in geothermics, crustal studies, seismotectonics, and regional geophysics/tectonics will be given preference. The successful candidate must hold a doctoral degree and will be expected to maintain a high level of research activity and to be active in the geophysics graduate program which involves 15–20 students (roughly ⅓ doctoral candidates). The geophysics program is well equipped and enjoys good support from the university administration. The deadline for applications is July 15, 1981 with the position to be filled prior to September 1, 1982. Applications and three letters of reference should be sent to:

Dr. Robert F. Roy
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968.

The University of Texas at El Paso is an equal opportunity/affirmative action employer.

Electron Microprobe Technical Specialist/University of Colorado. The department of Geological Science, University of Colorado, Boulder, seeks a person who will assume responsibility for the department's electron microprobe laboratory. Duties will include day-to-day operation of our MAC 400 microprobe equipped with a KEVEX EDS system, instruction of new operators, maintenance of the microprobe as well as other X-ray equipment within the Department, microprobe software and hardware development, and participation in research projects involving silicate, sulfide and oxide mineralogy. The job requires either a degree in electronic or electrical engineering, or two years of technical experience utilizing electronic instrumentation associated with an electron column instrument. An individual with an M.S. degree in Geology and microprobe experience will be considered highly desirable. Salary ranges from $20,000–$25,000 depending on experience. Please send, by August 15, letter of application and resume to Bruce Badger, Personnel Department, University of Colorado, 1511 University Avenue, Boulder, CO 80309.

The University of Colorado is an equal opportunity/affirmative action employer.

Research Seismologist/Solid Earth Geophysics. ENSCO, Inc. in Springfield, Virginia is seeking a Program Manager/Research Seismologist to support an expanding program in solid earth geophysics. Research areas will include: seismic network data processing associated with the detection, identification and location of natural and man-made seismic sources; earthquake characterization and source mechanism studies; explosion source characterization; and empirical studies using near field and far field seismic data. Experience in theoretical and observational seismology at regional and teleseismic distances, is highly desirable. Experience in digital time series analysis is desirable. Ph.D. in seismology is highly desirable, however, M.S. level with experience in earthquake and explosion seismology will be considered. Salary and benefits are extremely competitive. Resumes along with salary requirements should be submitted to the Personnel Department at the address below, Attention Code SAS, ENSCO, Inc., 5408-A Port Royal Road, Springfield, VA 22151.

Equal employment opportunity/AAP

Marine Sciences Institute/Research Assistant II. Salary $12,500 p.a. To conduct analyses of trace elements in seawater and other matrices by ultra-clean techniques; assist in the development of new analytic techniques; participate in oceanographic field work; assist in preparation of technical reports; coordinate laboratory and field programs. M.S. degree in appropriate area of analytical chemistry, geology or oceanography, or B.S. with 2 years experience. Experience with atomic absorption/emission spectrophotometry, gas chromatography, ultra-clean solvent extraction for trace metals, simple computer programming; experience working at sea. Reply to O. Wasiechuk at the University of Connecticut, Marine Sciences Institute, Groton, CT 06340.

Equal opportunity employer h/v.

Geophysicist/Tectonophysicist. The Department of Geology and Geophysics at the University of Wyoming has a tenure track opening at the Associate Professor level for a geophysicist/tectonophysicist. An interest in velocity measurements and other physical properties of rocks is essential. Additional interest in crustal structure and plate tectonics is desirable. Applicant should be able to relate studies of physical properties to field relationships. Ph.D. required.

Applications will be accepted through July 15, 1981. Applicants should send a vita, including names of three references, to:

Professor R. S. Houston
Department of Geology/Geophysics
University of Wyoming
Laramie, Wyoming 82071

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Marine Chemistry. Applications are invited for either of two tenure track faculty positions that carry teaching and research responsibilities. The level of appointment and salary will be commensurate with achievement and experience. One position is oriented toward the area of application of organic chemistry to natural systems. The other position is oriented toward research utilizing inorganic or radiochemistry in understanding atmospheric or oceanic processes. Ability to develop independent research programs will be a primary consideration.

Send resume, references and summary of research interests to: Search Committee, Division of Marine and Atmospheric Chemistry, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, Florida 33149.

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Scripps Institution of Oceanography

is soliciting applications for a postdoctoral fellowship in any aspect of marine geology, marine geochemistry, or marine geophysics for one year beginning fall 1981. Applicants should submit names of three references, bio-bibliographies, reprints, and a statement of research interest. Preference will be given to recent Ph.D.s. Salary will be approximately $19,500 depending upon experience and publications.

No moving expenses can be paid. Submit applications to Chairman, Geological Research Division, A-020, Scripps Institution of Oceanography, La Jolla, CA 92093, no later than August 1, 1981.

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Faculty Position
Space Physics
& Astronomy

The Department of Space Physics and Astronomy of Rice University expects to fill a regular faculty position beginning August 1982. Academic rank and tenure status will be determined on the basis of experience.

Preference will be given to experimentalists who are Principal Investigators for experiments on present or planned spacecraft missions. However, consideration will be given to other qualified candidates in the general areas of space physics, astrophysics, and atmospheric science.

Applicants should send resumes and bibliographies to

Professor A. J. Dessler
Chairman
Department of Space Physics and Astronomy
Rice University, Houston, TX 77001.

Rice University is an equal opportunity/affirmative action employer. No candidate is presently under consideration in advance of this notice.

Hydrogeochemist. Hydrogeochemist for Water Resources Center to conduct research studies including those related to geochemical and hydrologic analysis of Great Basin ground and surface water systems, and selling and hydrothermal geochemical problems. Duties include use of geochemical and hydrodynamic computer models and their adaptations to meet project needs; and design and management of field geochemical research projects. Requires MS or BS with five years experience in geochemistry, hydrology, or geology; experience in interactive computing with aqueous geochemical models; experience in design and implementation of field geochemical research projects including various field measurements and sample collection; knowledge of physical flow dynamics as applied to solute transport; demonstrated ability to work with others on a variety of research problems; knowledge of various laboratory procedures used in aqueous and mineral analysis. The successful candidate will be offered a six-month contract based on an annual salary of $18,000–$21,000, depending upon qualifications and experience. Send resume and letter of application, postmarked by July 15, 1981 to Personnel Department, Desert Research Institute, University of Nevada System, P.O. Box 60220, Reno, Nevada 89506.

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SERVICES

Scripps Remote Sensing Tutorials.

1A. *Overview of the Remote Sensing Facility*—This one-day seminar describes the data bases, sources and processing capabilities available at Scripps Institution of Oceanography, Remote Sensing Facility. A morning lecture will introduce past, current and future space platforms available for observation of the Oceans. A brief discussion of where and how to access this information will conclude the first part of the class.

The afternoon will include a demonstration of processing and displaying imagery obtained from TIROS-N, NOAA-6 and NIMBUS-7.

Classes will be held at the Helen Raitt Room SIO Library on Monday, April 20, 1981 and Monday, July 27, 1981, at 8:30 am. A nonrefundable fee of $50.00 must be submitted with the application. Enrollment limit—12.

2A. *Users Introduction to the Scripps Remote Sensing Facility*—This four-day workshop is intended exclusively for individuals who will be using the facility at Scripps. Two morning lectures will describe in detail the hardware, software and personnel resources available to oceanographers. Existing data bases, their characteristics, location, mode and cost of access will be covered. Basics of image processing will be introduced along with in-depth look at the interactive Digital Image Manipulation System used at the SRSF.

The two lectures will be followed by afternoon lab sessions which consist of hands-on exercises to familiarize users with the hardware/software at the facility. The third morning will be devoted to train users in realtime spacecraft tracking and data recording and acquisition.

The remainder of the 3rd day and the entire 4th day will be used to work with users on a one-to-one basis. Attendees are encouraged to bring their own digital tapes with data of interest to them, which can be used during this last portion of the workshop.

Classes will be held in the Helen Raitt Room SIO Library starting on Tuesday, April 21, 1981 and Tuesday, July 27, 1981 at 8:30 am. A fee of $335.00 must be submitted with each application. Enrollment limit—6.

For more information regarding applications, fees, etc., please contact University of California at San Diego, SRSF/SIO, Mail Code A-030, La Jolla, California 92093 or (714) 452-2292.

ANNOUNCEMENTS

25th Annual Report on Research Under Sponsorship of The Petroleum Research Fund. Containing 896 technical progress reports, bibliography, and information on the ACS-PRF program of grants-in-aid for ". . . advanced scientific education and fundamental research in the 'petroleum field'," is available gratis upon request to: The Petroleum Research Fund, American Chemical Society, 1155 Sixteenth Street, N.W., Washington, D.C. 20036.

Meetings

Call for Papers

Ocean Sciences: AGU/ASLO Joint Meeting

A joint meeting of the American Geophysical Union's Oceanography Section and the American Society of Limnology and Oceanography will be held February 16–19, 1982, in San Antonio, Texas. The El Tropicano Hotel is headquarters for the meeting, with additional housing available at the St. Anthony and the Gunter hotels.

Abstracts must be received at the AGU office by 5 P.M. on November 10 to be on time. Late abstracts (1) may be summarily rejected by program chairman, (2) may not be published in advance of the meeting, and (3) if accepted, will be charged a $25 late fee in addition to the regular publication charge.

General Regulations

Abstracts may be rejected without consideration of their content if they are not received by the deadline or are not in the proper format.

There is a publication charge of $40 ($30 if prepaid) for each abstract. The publication charge is $20 if the first author is a student. Both invited and contributed papers are subject to the publication charge. Prepayment of the publication charge can save you money. Send a check for $30 with your abstract ($15 for students).

The abstract must be received at AGU by November 10 to avoid an additional $25 charge.

Authors will be notified by mail in early January of the status of their papers.

Abstracts

Use standard AGU format and send original and two copies of abstracts to AGU Ocean Sciences Meeting, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Abstracts will be published in *Eos*, January 19, 1982. Copies will be sent to all ASLO members.

The abstract page is divided into two parts; the abstract itself and the submittal information. Follow the instructions for both carefully. Abstracts that exceed the noted size will be trimmed to conform to the proper dimensions.

Submission of an abstract for an AGU meeting is presumed to carry with it permission for AGU to reproduce the abstract in all editions of *Eos* and in the programs and reports relating to the meeting; it is also presumed to permit the free copying of those papers. Although *Eos* is a copyrighted journal, authors are not requested to transfer copyright; copyright, where it exists, will be reserved by the authors.

Program Committee

Convenors: Worth D. Nowlin, Jr., Department of Oceanography, Texas A&M University, College Station, TX 77843, (713) 845-2947; Richard W. Eppley, Institute of Marine Resources, A-018, S.I.O., University of California at San Diego, La Jolla, CA 92093; (714) 452-2338 (office), (714) 452-3194 (secretary).

Members: Charles D. Hollister, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, (617) 548-1400; Peter Jumars, Ocean Science and Technology Division, Office of Naval Research, 800 N. Quincy Street, Arlington, VA 22217, (202) 696-4590; Claire Schelske, Great Lakes Research Division, University of Michigan, Ann Arbor, MI 48109, (313) 764-2422; and Karl Turekian, Geology Department, Yale University, Box 2161, Yale Station, New Haven, CT 06520, (203) 436-0377.

Special Sessions

- Ocean Climate and Biological Productivity Connections
- Overview of Large Oceanographic Projects
- Biology and Physics of Gulf Stream Rings
- Relations Between Biology and Circulation in the Gulf of Mexico
- Geological Effects of Ocean Circulation
- Anthropogenic Inputs to the Ocean: Diverse Points of View
- Processes and Resources of the North Pacific Shelves
- Small Lake Limnology
- Marine and Freshwater Bioturbation
- Ocean-River Interaction: Sedimentation and Chemistry
- Particle Fluxes in the Water Column and Benthic Boundary Layer
- Relations between Mesoscale Physical and Biological Processes
- Coastal Processes
- Biological and Physical Measurement Techniques
- Microscale Processes and Effects on Biota
- Physics and Biology of Ice Edges
- Physical, Chemical and Biological Processes in Large Lakes

Sample Abstract

TECHNIQUE FOR THE PREPARATION OF ABSTRACTS

F. R. S. T. Author (School of Oceanography Hydro University, Watertown, Mass. 02172)
S. C. N. D. Author (USGS, Woods Hole, Mass. 02543)

Follow this example in typing the abstract. The printing plates will be prepared by photographing the abstracts exactly as they are received, except that abstracts exceeding the maximum length (20 cm) or width (10.4 cm) will be cut to conform. Use a good typewriter with a ribbon in good condition. A carbon ribbon gives the best results. Please use type of about this size. There will be a reduction of about 50% for the printed abstract volume.

Follow these guidelines:
(1) Type title in all capital letters.
(2) Leave one line blank after title.
(3) Type name of first author, affiliation, and address.
(4) Type names of second and following authors, if any, leaving no blank lines between authors.
(5) Underscore the name of author who will present paper.
(6) Leave one blank after author block.
(7) Hand-lettered symbols or Greek letters are acceptable.
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Submittal Information

1. Meeting name—Ocean Sciences 1982
2. Corresponding address.—Give complete address and phone number of author to whom all correspondence should be sent. Abbreviate as much as possible.
3. Kind of presentation—Indicate your preference with one of the following letters: O for oral, P for poster. The chairman may assign your paper to either of these types of presentation in order to fit his program plan.
4. Type title of special session (if any) to which submittal is made.
5. Give the percent of material previously presented or published and where.
6. Billing information:
   a. Complete billing address if other than the corresponding address (item 2 above).
   b. If purchase order is to be issued, indicate number. (Please have issuing department list name of first author and title of paper on P.O.)
   c. Student rate applicable.
7. Indicate whether paper is C (contributed) or I (invited). If invited, list name of inviter.

Abstract Deadline: November 10, 1981
Mail original and two copies to:
Ocean Sciences Meeting
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D.C. 20009

AGU Midwest Meeting

September 17–18
Minneapolis, Minnesota

Abstract Deadline: July 1
Convenor: V. Rama Murthy

Last Call

Papers and posters originating in or pertaining to the region are solicited for the following special sessions:

Mantle structure and dynamics. Contact Geoffrey Davies or Clam Chase.

Rock water interaction, hydrothermal processes and metallogenesis. Contact William Seyfried.

Precambrian crustal evolution of the North American continent. Contact Paul Weiblen.

Geomagnetism and paleomagnetism. Contact Subir Banerjee.

Hydrology of the mid-continental U.S. Contact H. O. Pfannkuch or E. C. Alexander, Jr.

Abstracts

Use standard AGU format (see page 20 of January 13 *Eos*) and send original and two copies of abstracts to AGU Midwest Meeting, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Abstracts will be published in *Eos*, with a substantive meeting report after the meeting. There will be no abstract charge.

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ANTON L. HALES SYMPOSIUM

The Geosciences Program of The University of Texas at Dallas will sponsor a Symposium entitled

"SOME RECENT ADVANCES IN GEOPHYSICS"

on October 5–8, 1981, in honor of Dr. Anton L. Hales on his 70th birthday.

The Symposium will consist of two days of invited talks by internationally known speakers from academia and industry on recent developments in geophysics with an emphasis on seismology. Topics will include recent COCORP results, modelling reflection seismograms, heterogeneous earth structure, attenuation of seismic waves, and global tectonics.

For additional details and registration information, contact Richard M. Mitterer or Ronald W. Ward, Programs in Geosciences, The University of Texas at Dallas, P.O. Box 688, Richardson, Texas 75080. Telephone: 214-690-2401.

Geophysical Year

(Boldface indicates meetings sponsored or cosponsored by AGU.)

1981

June 29–July 2 22nd United States Symposium on Rock Mechanics, Cambridge, Mass. Sponsor, Massachusetts Institute of Technology. (Barbara Dutton, Coordinator, Center for Advanced Engineering Study Seminars, MIT, Cambridge, MA 02139.)

June 29–July 3 Conference-Workshop on Heterogeneous Catalysis—Its Importance to Atmospheric Chemistry, Albany, N.Y. Sponsors, NSF, NASA. (V. A. Mohnen, Atmospheric Sciences Research Center, State Univ. of New York, Albany, NY 12222.)

June 29–July 11 Seminar on Fluid-Dynamical Problems in Astrophysics and Geophysics, Chicago, Ill. Sponsors, American Mathematical Society, Society for Industrial and Applied Mathematics. (Meeting Arrangements Department, American Mathematical Society, Post Office Box 6248, Providence, R.I.)

July 6–11 Geocongress '81-South African Geodynamics Project and 3rd International Platinum Symposium, Pretoria, South Africa. Sponsors, Geological Society of South Africa, South African National Committee for the International Union of Geological Sciences, Society of Economic Geologists. (The Symposium Secretariat S. 217, CSIR, P.O. Box 395, Pretoria 0001 Republic of South Africa.)

July 8–10 National Conference on Environmental Engineering, Atlanta, Ga. Sponsor, Environmental Engineering Division of American Society of Civil Engineers. (F. Michael Saunders, 1981 National Conference on Environmental Engineering, School of Civil Engineers, Georgia Institute of Technology, Atlanta, GA 30332.)

July 15–17 Summer Computer Simulation Conference, Washington, D.C. Sponsors, Instrument Society of America, the Society for Computer Simulation. (William E. Buchanan, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20810.)

July 21–23 **Chapman Conference on Spatial Variability in Hydrologic Modeling,** Fort Collins, Colo. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

July 21–30 21st General Assembly of IASPEI, London, Ontario, Canada. (A. E. Beck, Department of Geophysics, Univ. of Western Ontario, London, Ontario N6A 5B7 Canada.)

July 27–30 **Eighth International Symposium on Urban Hydrology, Hydraulics, and Sediment Control,** Lexington, Ky. (Don J. Wood, Department of Civil Engineering, 206B Anderson Hall, Univ. of Kentucky, Lexington, KY 40506.)

Aug. 3–15 IAGA Fourth Scientific Assembly, Edinburgh, United Kingdom. (B. R. Leaton, Institute of Geological Sciences, Edinburgh EH9 3LA United Kingdom.)

Aug. 4–7 International Conference on Energy Education, Providence, R.I. (Donald Kirwan, Conference Chairman, Office of Energy Education, Univ. of Rhode Island, Kingston, RI 02881.)

Aug. 9–15 Symposium on Variations in the Global Water Budget, Oxford, United Kingdom. Sponsors, ICCL, IAHS, INQUA. (Prof. R. E. Newell, Department of Meteorology, 54-1520, MIT, Cambridge, MA 02139.)

Aug. 9–18 International Congress of Surveyors, F.I.G., Montreux, Switzerland. Sponsor, Fédération Internationale Des Geometres. (American Congress on Surveying and Mapping, 210 Little Falls Street, Falls Church, VA 22046.)

Aug. 10–14 International Conference on Basement Tectonics, Oslo, Norway. Sponsor, Norwegian Petroleum Society. (Roy H. Gabrielsen, Department of Geology, Univ. of Oslo, P.O. Box 1047, Blindern, Oslo 3 Norway; or Don L. Baars, Department of Geology, Fort Lewis College, Durango, CO 81301.)

Aug. 10–14 Water Forum '81: Technical State of the Art Exchange, San Francisco, Calif. Sponsors, American Society of Civil Engineers, Irrigation and Drainage Division, Committee on Drainage. (P. M. Meyers, 509 North Roosevelt Blvd., Apt. D-105, Falls Church, VA 22044.)

Aug. 10–19 20th General Assembly of the International Union of Radio Science, Washington, D.C. (R. Y. Dow, National Academy of Sciences, 2101 Constitution Ave., Washington, DC 20418.)

Aug. 17–28 Third Scientific Assembly of IAMAP with Extraordinary General Assembly, Hamburg, Federal Republic of Germany. (S. Ruttenburg, NCAR, P.O. Box 3000, Boulder, CO 80307.)

Aug. 17–18 Open Symposium on Mathematical Models of Radio Propagation, Washington, D.C. Sponsor, URSI. (J. R. Wait, Bldg. 20, Electrical Engineering Department, Univ. of Arizona, Tucson, AZ 85721.)

Aug. 17–22 **Ninth International Symposium on Earth Tides,** New York, N.Y. Sponsors, IAG, IUGG, Columbia Univ. (J. T. Kuo, 828 S.W. Mudd, Columbia Univ., New York, NY 10027.)

Aug. 18–21 Second Biennial Conference and Exhibition of the Australian Society of Exploration Geophysicists, Adelaide, South Australia. (J. Haigh, Conference Chairman, P.O. Box 42, Unley, South Australia 5061.)

Aug. 20–21 Second International Symposium on Computer-Aided Seismic Analysis and Discrimination, North Dartmouth, Mass. Sponsors, Electrical Engineering Department, Southeastern Massachusetts University, IEEE Computer Society, IEEE Acoustics, Speech and Signal Processing Society. (C. H. Chen, Electrical Engineering Department, Southeastern Massachusetts University, North Dartmouth, MA 02747.)

Aug. 24–26 International Symposium on Management of Geodetic Data, Copenhagen, Denmark. Sponsors, IAG, the Danish National Committee of IUGG, Geodaetisk Institut. (C. C. Tscherning, International Symposium Management of Geodetic Data, Geodaetisk Institut, Gamlehave Alle 22, Charlottenlund DK-2920 Denmark.)

Aug. 24–29 Eighth Annual Meeting of the European Geophysical Society, Uppsala, Sweden. (C.-E. Lund, Chairman Local Organizing Committee, Institute of Solid Earth Physics, Uppsala University, Box 556, 22 Uppsala, Sweden.)

Aug. 25–27 The Royal Institution of Chartered Surveyors Centenary Celebration, London, England. (Representative Radlinski, American Congress on Surveying and Mapping, 210 Little Falls Street, Falls Church, VA 22046.)

Aug. 28–Sept. 9 Arc Volcanism Symposium, Tokyo, Japan. Sponsors, Volcanological Society of Japan, IAVCEI. (Daisuke Shimozuru, IAVCEI Symposium on Arc Volcanism, Earthquake Research Institute, Univ. of Tokyo, Bunkyo-ku, Tokyo 113 Japan.)

Aug. 31–Sept 2 Third International Colloquium on Mars, Pasadena, Calif. Sponsors, NASA, Lunar and Planetary Institute, Division of Planetary Sciences of the AAS. (Conway W. Snyder, Jet Propulsion Laboratory, Pasadena, CA 91109.)

Aug. 31–Sept. 5 Symposium on Geodetic Networks and Computations, Munich, West Germany. Sponsor, IAG. (Deutsche Geodätische Kommission, Bayerischen Akademie der Wissenschaften, Marstallplatz 8, D-8000 Munchen 22.)

Sept. United Nations Symposium on Water Management in Industrialized Areas, Lisbon, Portugal. (Chairman of the Executive Committee, International Symposium on Water Management in Industrial Areas, Portuguese Water Resources Association, c/o LNEC, Av. do Brasil, 101, 1799 Lisbon, Portugal.)

Sept. 7–12 Third International Symposium on Antarctic Glaciology, Columbus, Ohio. Sponsors, International Commission on Snow and Ice, International Glaciological Society. (Institute of Polar Studies, Ohio State Univ., 125 S. Oval Mall, Columbus, OH 43210.)

Sept. 8–12 American Society of Photogrammetry-American Congress on Surveying and Mapping Fall Convention, San Francisco, Calif. (L. W. Aggers, USGS, 345 Middlefield Road, Mail Stop 31, Menlo Park, CA 94025.)

Sept. 13–17 National Water Well Association 33rd Annual Convention and Groundwater Technology Education Session, Kansas City, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 16–18 **Oceans '81,** Boston, Mass. Sponsors, Marine Technology Society, IEEE Council of Oceanic Engineering, AGU. (R. Nagle, Publicity Manager, Raytheon Company, 141 Spring St., Lexington, MA 02173.)

Sept. 17–18 **Midwest Meeting,** Minneapolis, Minn. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Sept. 17–18 **Pacific Northwest Regional Meeting,** Ellensburg, Wash. (Bob Bentley, PNAGU, Central Washington University, P.O. Box 1000, Department of Geology, Ellensburg, WA 98920.)

Sept. 20–22 National Water Well Association 34th Annual Convention and Exposition, Atlanta, Ga. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 28–Oct. 10 NATO Advanced Study Institute on Chemistry of the Unpolluted and Polluted Troposphere, Corfu, Greece. (W. Jaeschke, Center of Environmental Protection, University of Frankfurt, Robert-Mayer-Str. 11, 6000 Frankfurt/Main, FRG.)

Oct. 6–8 International Conference on Time Series Methods in Hydrosciences, Burlington, Ontario. Sponsors, National Water Research Institute of the Canada Centre for Inland Waters and Water-Resources Branch of Ontario's Ministry of Environment. (A. El-Shaarawi, Aquatic Physics and Systems Division, NWRI, Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario L7R 4A6 Canada.)

Oct. 7–9 John Muir Geophysical Society's Fourth Nonannual Meeting, Lake Arrowhead, Calif. (M. McNutt, USGS, Menlo Park, CA 94025.)

Oct. 11–14 Coastal Society's Seventh Annual Conference, Galveston, Tex. (N. West, Coastal Society Conference, Department of Geography and Marine Affairs, Univ. of Rhode Island, Kingston, RI 02881.)

Oct. 11–15 51st Annual International Meeting of the Society of Exploration Geophysicists, Los Angeles, Calif. (William L. Baker, Technical Program Chairman, c/o Chevron Oil Field Research Co., Box 446, La Habra, CA 90631.)

Oct. 13–15 Fifth Geopressured-Geothermal Energy Conference, Baton Rouge, La. Sponsors, Louisiana Geological Survey, Department of Natural Resources; Energy Programs Office, Louisiana State University; U.S. Department of Energy. (Ann Bachman, Conference Coordinator, Energy Programs Office, 105 Hill Memorial, Louisiana State Univ., Baton Rouge, LA 70803.)

Oct. 13–16 Division of Planetary Sciences of the American Astronomical Society Annual Meeting, Pittsburgh, Pa. (B. Hapke, Dept. of Geology and Planetary Science, 321 Old Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15260.)

Oct. 14–16 Third Surveying and Mapping Colloquium for the Petroleum Industry, Banff, Alberta, Canada. Sponsor, Canadian Petroleum Association. (Liz Hampton, Canadian Petroleum Association, 1500, 633 Sixth Ave., S.W., Calgary, Alberta, Canada T2P 2Y5.)

Oct. 16–22 Earth Impact Conference, Snowbird, Utah. Sponsors, Lunar and Planetary Institute, National Academy of Sciences. (Earth Impact Conference, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.)

Oct. 22–24 Fourth Conference on the Physics of the Jovian and Saturnian Magnetospheres, Laurel, Md. Sponsor, NASA. (S. M. Krimigis, Applied Physics Laboratory, Johns Hopkins Univ., Laurel, MD 20810.)

Oct. 26–30 Symposium on Quaternary Land-Sea Migration Bridges and Human Occupation of Submerged Coastlines, La Jolla, Calif. Sponsors, Quaternary Shorelines Commission of the International Union for Quaternary Research, Scientific Committee of the World Confederation of Underwater Activities. (Patricia M. Masters, Scripps Institution of Oceanography, A-012, La Jolla, CA 92093.)

November 1–5 Sixth Biennial International Estuarine Research Conference, Gleneden Beach, Oreg. Sponsor, Estuarine Research Federation. (Jay F. Watson, Treasurer, USFWS Suite 1692, 500 N.E. Multnomah Street, Portland, OR 92232.)

Nov. 2–6 International Conference on the Venus Experiment, San Francisco Bay Area, Calif. Sponsor, NASA. (Dr. Lawrence Colin, Ames Research Center, Moffett Field, CA 94035.)

Nov. 9–11 Special Conference on the Mechanical Behavior of Salt, University Park, Pa. Sponsor, Rock Mechanics Laboratory, Department of Mineral Engineering, Pennsylvania State University. (H. Reginald Hardy, Jr., Rock Mechanics Laboratory, Room 117, Mineral Sciences Building, Pennsylvania State University, University Park, PA 16802.)

Nov. 9–20 Second Symposium on Geodesy in Africa, Nairobi, Kenya. Sponsors, IAG, IUGG Local Committee of Kenya, IUGG Committee on Advice to Developing Countries, African Association of Cartography. (R. Omondi, Survey of Kenya, P.O. Box 30046, Nairobi, Kenya.)

Nov. 30–Dec. 11 43rd Session of the International Statistical Institute, Buenos Aires, Argentina. (Jim R. Wallis, IBM, Research Division, Box 218, Yorktown Heights, NY 10566; or G. B. Watson, Bernoulli Society for Mathematical Statistics and Probability, Department of Statistics, Princeton Univ., Princeton, NJ 08544.)

Dec. 3–5 **Topical Conference on the Processes of Planetary Rifting,** San Francisco, Calif. Sponsor, Lunar and Planetary Institute. (Rift Meeting, Projects Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.)

Dec. 7–11 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 16–18 Annual International Meeting of the Working Group on Mediterranean Ophiolites, Florence, Italy. (Luigi Beccaluva, Istituto di Petrografia, Via Gramsci 9, 43100 Parma, Italy.)

1982

Jan. 11–14 Symposium on the Understanding of Hydrologic Processes at the Basin Scale, Caracas, Venezuela. Sponsors, Universidad Simón Bolívar, IAHS. (Ignacio Rodriguez-Iturbe, Universidad Simón Bolívar, Apartado Postal 80.659, Caracas 1081, Venezuela.)

Feb. 8–12 **Third International Geodetic Symposium on Satellite Doppler Positioning,** Las Cruces, N. Mex. Sponsors, Defense Mapping Agency, National Ocean Survey, AGU. (Richard Peat, Defense Mapping Agency, Hydrographic/Topographic Center, 6500 Brooks Lane, N.W., Washington, DC 20315.)

Feb. 16–19 **Ocean Sciences: AGU/ASLO (American Society of Limnology and Oceanography) Joint Meeting,** San Antonio, Tex. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Mar. 22–26 International Symposium on Hydrothermal Reactions, Yokohama, Japan. Sponsor, Tokyo Institute of Technology. (Shigeyuki Sōmiya, Research Laboratory of Engineering Materials, Tokyo Institute of Technology, Nagatsuta, Midori, Yokohama, 227 Japan.)

Mar. 24–27 Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, Hayward, Calif. Sponsors, USGS, East Bay Council on Surveying and Mapping, Calif. Div. of Mines and Geol., Woodward-Clyde Consultants, Calif. St. Univ. at Hayward. (Sue Hirschfeld, Dept. of Geological Sciences, California State University, Hayward, CA 94542.)

Apr. 11–16 Penrose Conference on Antarctica, Shenandoah National Park, Va. Sponsor, GSA. (Ian W. D. Dalziel, Lamont-Doherty Geological Observatory, Columbia University, Palisades, NY 10964.)

April 16–21 Cordilleran Section, Geological Society of America and Seismological Society of America Annual Meeting, Anaheim, Calif. (Neil Maloney, Earth Science Department, California State Univ., Fullerton, CA 92634.)

April 27–29 **Chapman Conference on Rainfall Rates,** Urbana, Ill. (Meetings, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.)

May 3–7 **14th International Liège Colloquium on Ocean Hydrodynamics,** Liège, Belgium. Sponsors IAPSO, Unesco Marine Sciences Division, EGS, Intergovernmental Oceanographic, AGU. (Jacques C. J. Nihoul, University of Liège, Mécanique des Fluides Géophysiques-Environment, B6- Sart Tilman, B-4000 Liège, Belgium.)

May 7–20 General Meeting of IAG, Tokyo, Japan. (I. Nakagawa, Geophysical Institute, Kyoto University, Sakyo-ku, Kyoto 606 Japan.)

May 10–12 Fourth International Conference on Planning and Management of Water Resources for Industrial, Agricultural, and Urban Use, Marseilles, France. Sponsors, Commission Européenne Méditerranéenne de Planification des Eaux (C.E.M.P.E.), Société des Eaux de Marseille (S.E.M.), the Bureau de Recherches Géologiques et Minières (B.R.G.M.), Centre de Formation Internationale à la Gestion des Ressources en Eau (CEFIGRE), UNESCO, Commission des Communautés Européennes, Association des Hydrogéologues (AIH). (Secretariat de la Conférence, Société des Eaux de Marseille, 25 rue Edouard Delanglade—13006 Marseille, France.)

May 24–June 4 International Solar-Terrestrial Physics Symposium, Ottawa, Ontario, Canada. (Professor Liu, University of Illinois, Urbana, IL 61801.)

May 24–June 4 24th Plenary Meeting of COSPAR Ottawa, Ontario, Canada. (Dean Kastel, Space Sciences Board, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington DC 20418.)

May 25–28 **Symposium on the Composition of Nonurban Troposphere,** Williamsburg, VA. Sponsors, AMS, NASA, AGU. (Jack Fishman, Mail Stop 401-B, NASA Langley Research Center, Hampton, VA 23665.)

May 31–June 4 **AGU Spring Meeting,** Philadelphia, Pa. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

June 13–17 International Symposium on Hydrometeorology, Denver, Colo. Sponsor, American Water Resources Association. (A. I. Johnson, Woodward-Clyde Consultants, 2909 West 7th Ave., Denver, CO 80204.)

June 15–18 **International Conference on Rainwater Cistern Systems,** Honolulu, Hawaii. Sponsors, University of Hawaii's Water Resources Research Center, AGU. (Yu-Si Fok, General Conference Chairman, Water Resources Research Center, Univ. of Hawaii, 2540 Dole Street, Honolulu, HI 96822.)

June 27–July 2 Fifth International Conference on Geochronology, Cosmochronology, and Isotope Geology, Nikko National Park, Japan. (K. Shibata, Geological Survey of Japan, Higashi 1-1-3, Yatabe, Ibaraki 305 Japan.)

July 19–30 Scientific Meeting of IAHS with Extraordinary General Assembly, Exeter, United Kingdom. (John C. Rodda, Department of the Environment, Water Data Unit, Reading Bridge House, Reading RG1 8PS United Kingdom.)

Aug. 2–13 Joint Oceanographic Assembly, Halifax, Nova Scotia, Canada. Sponsor, Scientific Committee on Oceanic Research. (Leo O'Dunn, National Steering Committee for JOA, c/o Canadian Committee on Oceanography, 240 Sparks St., Ottawa, Ontario K1A 0E6 Canada.)

Aug. 2–6 Second International Symposium/Workshop on Solar-Terrestrial Influences on Weather and Climate, Boulder, Colo. Sponsor, Lockheed Palo Alto Research Laboratory. (Billy M. McCormac, Lockheed Palo Alto Research Laboratory, Dept. 52-13/8202, 3251 Hanover Street, Palo Alto, CA 94304.)

Aug. 15–21 Fourth International Symposium on Antarctic Earth Sciences, Ingle Farm, South Australia, Australia. Sponsors, Australian Academy of Science, Australian Academy of Technological Sciences, International Union of Geological Sciences, Scientific Committee on Antarctic Research, Geological Society of Australia, Inc., Univ. of Adelaide. (J. B. Jago, South Australian Institute of Technology, P.O. Box 1, Ingle Farm, South Australia, Australia 5098.)

Aug. 15–22 International Meeting on Generation of Major Basalt Types, Reykjavík, Iceland. Sponsors, IAVCEI, IAGC. (Basalt Meeting, c/o G. E. Sigvaldason, Nordic Volcanological Institute, 101 Reykjavík, Iceland.)

Aug. 16–22 IAVCEI and IAGC Joint Meeting, Reykjavík, Iceland. (G. E. Sigvaldason, Nordic Volcanological Institute, Univ. of Iceland, Geosciences Building, 101 Reykjavík, Iceland.)

Aug. 22–28 11th International Congress on Sedimentology, Hamilton, Ontario, Canada. Sponsor, IAS. (IAS Congress 1982, Department of Geology, McMaster University, Hamilton, Ontario L8S 4M1, Canada.)

Aug. 22–28 **Third Circum-Pacific Energy and Mineral Resources Conference,** Honolulu, Hawaii. Sponsor, IUGS. (AAPG Convention Department, P.O. Box 979, Tulsa, OK 74101.)

Aug. 23–27 Second Symposium on Applied Glaciology, Hanover, N.H. Sponsor, International Glaciology Society. (Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom.)

Aug. 24–27 Ninth Annual Meeting of the European Geophysical Society, Leeds, United Kingdom. (J. C. Briden, Department of Earth Sciences, University of Leeds, Leeds LS2 9JT, England.)

Sept. Third International Kimberlite Conference, Clermont-Ferrand, France. (Francoise Boudier, Université de Nantes, Laboratoire de Tectonophysique, 2 Rue de la Houssinière, 44072 Nantes, France.)

May or Sept. Scientific Meeting of IAPSO, Halifax, Canada. (E. C. LaFond, LaFond Oceanic Consultants, P.O. Box 7325, San Diego, CA 92017.)

Dec. 6–10 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

1983

July 18–23 Fourth International Conference on Permafrost, Fairbanks, Alaska. Sponsors, National Academy of Sciences, State of Alaska. (L. De Goes, Polar Research Board, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418.)

Aug. 15–28 18th General Assembly of IUGG, Hamburg, Federal Republic of Germany. (P. Melchior, Observatoire Royal de Belgique, Avenue Circulaire 3, B-1180 Bruxelles, Belgium.)

Aug. 27 Symposium Commemorating the 100th Anniversary of the Mount Krakatau Eruption, Jakarta, Indonesia. Sponsor, Indonesian Institute of Sciences. (Didin Sastrapradja, Deputy Chairman for Natural Sciences, LIPI JL, Tauku Chik Ditiro 43, Jakarta, Indonesia.)

Sept. 12–14 National Water Well Association 35th Annual Convention and Exposition, St. Louis, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Dec. 5–9 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

AAPG American Association of Petroleum Geologists
AMS American Meteorological Society
ASCE American Society of Chemical Engineers
GSA Geological Society of America
IAG International Association of Geodesy
IAGA International Association of Geomagnetism and Aeronomy
IAHS International Association for Hydrological Sciences
IAMAP International Association of Meteorology and Atmospheric Physics
IAPSO International Association of Physical Sciences of the Ocean
IASPEI International Association of Seismology and Physics of the Earth's Interior
IAVCEI International Association of Volcanology and Chemistry of the Earth's Interior
IUGS International Union of Geological Sciences
IWRA International Water Resources Association
MSA Mineralogical Society of America
SEG Society of Exploration Geophysicists
SEPM Society of Economic Paleontologists and Mineralogists
URSI International Union of Radio Science

FUTURE AGU MEETINGS

Fall Meetings
December 7–11, 1981, San Francisco
December 6–10, 1982, San Francisco
December 5–9, 1983, San Francisco

Spring Meetings
May 31–June 4, 1982, Philadelphia

AGU

Nominations for New VGP Award Sought

At the 1981 Spring Meeting in Baltimore, the VGP Executive Committee voted to establish a VGP Award. The guidelines for the award are as follows:

I. Basis for the Award

The award is to be given for a single outstanding contribution to volcanology, geochemistry, or petrology made during the preceding 5 years. The contribution may be: (1) a single outstanding paper published in any journal; (2) a series of papers which, taken together, constitute an outstanding contribution; and (3) any other contribution that the Selection Committee considers worthy. The award will be accompanied by a suitable certificate, with the recipient's name and year of award, signed by the president of the VGP Section.

II. Number of Awards

The award may be given to as many as five or as few as zero individuals during any calendar year. Multiple awards may be either shared awards or separate awards, as appropriate.

III. Nominations

Nominations for the award may be made by any member of AGU. They must be accompanied by a written statement of the basis for nomination. Copies of the contribution(s) for which the person is nominated should accompany the nomination statement if appropriate. Nominations may be submitted to the chairman of the Selection Committee or to any officer of the VGP Section for transmittal to the Committee.

IV. Eligibility

Any member of the scientific community is eligible for the award, but no individual may receive the award more than once. The Committee is charged with seeking out scientists whose work has not been recognized by the receipt of other awards, but this charge is not a restriction on the award.

V. Selection Committee

The Selection Committee shall consist of five AGU members affiliated with the VGP Section. Each member shall have a tenure of 3 years. Terms will overlap to provide continuity to the Committee. One or two members—as appropriate—shall be appointed each year by the president of the VGP Section after consultation with the other VGP officers. The VGP President shall determine the tenures of the members of the initial Selection Committee.

VI. Committee Chairmen

The chairman of the Selection Committee will be selected by the president of the VGP Section from among the second- or third-year members of the Committee.

VII. Committee Recommendations

The Selection Committee shall make an annual recommendation to the Executive Committee of the VGP Section as to who should receive the award. The recommendation shall include the nominating statement(s) of qualifications and a draft, or drafts, of suitable citations. The Executive Committee of the VGP Section has veto power and may refuse or return any recommendation to the Selection Committee for further consideration. The Executive Committee shall reach their decisions by majority vote of those in attendance or communication. In case of tie votes the VGP Section President will have the final authority. The Selection Committee shall also submit the names and qualifications of all nominees considered for the award to the Executive Committee, who will consider the nominees for possible nomination for AGU Fellowship.

VIII. Award Schedule

May—Announcement in *Eos* soliciting nominations from AGU membership. July—Selection Committee members and AGU membership make nominations to the chairman August—Committee comes to a consensus. September—Committee recommends the annual recipients of the award to the VGP Executive Committee. October—Executive Committee takes action on recommendations. Secretary arranges for announcement in *Eos* and for certificates. December—Award made at Western Meeting of AGU Executive Committee may decide to have award made at the Fall Eastern Meeting if circumstances warrant delay in presentation. April—President of section selects new members for Committee and designates new chairman in accordance with paragraphs V and VI above.

Nominations for the first VGP Award, which will be presented at the 1981 Fall Meeting in San Francisco, are now being sought. AGU members should send nominations and appropriate supporting material to the VGP President (Wallace Broecker), President-Elect (Joseph V. Smith), or Secretary (G. Brent Dalrymple) for transmittal to the Selection Committee.

GAP

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Particles and Fields—Magnetosphere

5715 Electric fields
PAIRED ELECTROSTATIC SHOCKS
M. Temerin (Space Sciences Laboratory, University of California, Berkeley, California 94720) M. H. Boehm and F. S. Mozer
Examination of 31 paired electrostatic shocks from a portion of the S3-3 satellite data set has shown that in 30 cases the electric field in the equatorward half of the paired shock pointed poleward while the electric field in the poleward half of the paired shock pointed equatorward. At the same time the electron, ion, and wave data indicated the presence of an electric field parallel to the magnetic field in the region between the paired shocks. This parallel electric field was at an altitude below that of the satellite and pointed out of the ionosphere so as to accelerate ions upward. A comparison of the potential across the electrostatic shock and the energy of the corresponding ion beam at the energy of maximum flux gives reasonable agreement. This provides convincing evidence that the potential contours associated with paired electrostatic shocks close across the magnetic field to produce the auroral electron acceleration responsible for inverted-V particle distributions and auroral arcs. (Electrostatic shocks, auroral acceleration).
Geophys. Res. Lett., Paper 1L0849

5738 Magnetic Tail
ESTIMATE OF THE NORTH-SOUTH ELECTRIC FIELD COMPONENT IN THE MAGNETOTAIL LOW LATITUDE BOUNDARY LAYER
M. Candidi and S. Orsini (IFS/CNR CP 27, 00044 Frascati (Roma) Italy)
The measurements of O^+ ions drift velocity in the magnetotail boundary layer are used to infer the North-South E_z component of the local electric field. It is shown that E_z is generally a substantial component of the field and that it reverses its sign from the dawn to the dusk side of the northern magnetotail between $X_{SM} = -15\ R_E$ and $X_{SM} = -35\ R_E$. (Electric field, geomagnetic tail, magnetotail boundary layer).
Geophys. Res. Lett., Paper 1L0567

5755 Plasma Instabilities
STABILIZATION OF THE ELECTROSTATIC KELVIN-HELMHOLTZ INSTABILITY IN HIGH β PLASMAS
J. Huba, Naval Research Laboratory, Washington, D.C.
A fully self-consistent theory of the electrostatic Kelvin-Helmholtz instability in finite β plasma is presented. The instability is driven by a parallel velocity flow which is sheared transverse to the magnetic field. The important features of our analysis are: Vlasov theory is used so that finite Larmor radius effects and wave-particle resonances are properly treated; the complete coupling of electrostatic and electromagnetic oscillations is considered (i.e., both resonant and nonresonant) are treated self-consistently. The primary result is that the electrostatic Kelvin-Helmholtz instability is stable in high β plasmas. The actual value of β for stabilization depends upon the parameters. The stabilization is mainly attributed to resonant and nonresonant VB effects. These results are applied to several space plasmas (i.e., polar cusp, cometary tails, magnetopause) and estimates of the anomalous diffusion coefficient associated with this instability are presented.
J. Geophys. Res., Blue, Paper 1A0919

5755 Plasma Instabilities
TRANSIENT NONLINEAR PITCH ANGLE SCATTERING OF ENERGETIC ELECTRONS BY COHERENT VLF WAVE PACKETS IN THE MAGNETOSPHERE
T. F. Bell (Radioscience Laboratory, Stanford University, Stanford, Ca., U.S.A.) U. S. Inan
With the aid of adiabatic theory, a study is made of the transient nonlinear pitch angle scattering experienced by energetic electrons under the influence of coherent VLF wave packets in the magnetosphere. Finite wave packets of both fixed and variable frequency are considered, as are wide ranges of L-shell, wave frequency and wave amplitude. Our results indicate that large mean pitch angle changes can be induced in the portion of the energetic particle population which undergoes a nonlinear cyclotron resonance interaction with the wave packet. Two classes of nonlinearly interacting particles are involved, the nonlinearly resonant particles trapped in the wave and the nonlinearly resonant nontrapped particles. It is shown that the mean pitch angle change of these two classes of particles are of opposite sign, but that the mean pitch angle change of the ensemble can still be significant. In the case of fixed-frequency wave packets on magnetic shells near L = 4, trapped particles typically experience pitch angle changes of 1° or more for moderate wave amplitudes (~10 mγ). In the case of variable-frequency wave packets, similar changes may be produced with much lower wave amplitudes (~1 mγ). We conclude that the utilization of transient nonlinear pitch angle scattering effects offers interesting options for energetic particle control during ground- or space-based VLF wave-injection experiments.
J. Geophys. Res., Blue, Paper 1A0422

5760 Plasma Motion, Convection, or Circulation
PROPAGATING SUBSTORM INJECTION FRONTS
T.E. Moore, (Space Science Center, University of New Hampshire, Durham, N.H. 03824) R.L. Arnoldy, J. Feynman, and D.A. Hardy
The geosynchronous ATS-6 Environmental Measurements Experiment was operated during fifteen evening passes when the SCATHA spacecraft was within 1-2 R_E and both spacecraft were near the geomagnetic equator. Numerous, well defined substorm injections were recorded at both spacecraft with varying local time and radial separation. Accurate delay timing was possible since these events exhibit abrupt and essentially dispersionless (to within 10 sec) plasma flux changes which replace cool pre-existing plasma with hot quasi-Maxwellian distributions. The hot plasma propagates Earthward in close association with an equally abrupt magnetic field increase at velocities in the range of 10-100 km/sec. On this basis we identify the agent of injection as the induced electric field of the Earthward propagating compression wave observed by Russell and McPherron, and as related to the propagating particle structure as the injection front. These dramatic synchronous orbit electron injection signatures are produced mainly by a boundary motion rather than by local acceleration of plasma. However, we find some evidence that the plasma sheet electrons are weakly "heated" by the passage of each compression wave, the energy appearing mainly in the high energy tail of the distribution. The spectral change we observe argues convincingly that the boundary in question is a precipitation-flow boundary layer and that the outer-Earth plasma sheet is significantly degraded in average energy by the addition of ionospheric plasma, especially secondary electrons emitted by the ionosphere due to precipitating energetic electrons. The presence of significant ∂B/∂t requires that a change of mapping occur between the equatorial plane and the ionosphere, the sense being such as to map the Earthward moving injection front to a relatively fixed latitude in the ionosphere. The lack of equatorward auroral expansion during substorms is thus fully consistent with Earthward plasma injection.
J. Geophys. Res., Blue, Paper 1A0733

5760 Plasma motion, convection, or circulation
ON THE VELOCITY DISTRIBUTION OF ION JETS DURING SUBSTORM RECOVERY
J. Birn (Ruhr-Universität Bochum, 4630 Bochum, W. Germany), T.G. Forbes, E.W. Hones, Jr., S.J. Bame (University of California, Los Alamos National Laboratory, Los Alamos, NM 87545, USA) and G. Paschmann (Max-Planck-Institut für Physik

6199 General or miscellaneous
THE EFFECT OF THERMAL CYCLING ON THE SEISMIC QUALITY FACTOR, Q, OF SOME SEDIMENTARY ROCKS
V.A. Clark and T.W. Spencer (Dept. of Geophysics, Texas A&M University, College Station, TX 77843) B.R. Tittmann (Rockwell International Science Center, Thousand Oaks, CA 91360)

Changes in Q in rocks in response to thermal cycling can result from the removal of physisorbed water, an increase in the crack density and therefore the internal surface area, at temperatures greater than 400°C, the removal of chemisorbed OH groups which are the adsorption sites for physisorbed water, and the dehydration of clays.

When rocks are heated to temperatures of 100-200°C, the change in Q is reversible and is due to the removal of physisorbed water. Sioux quartzite and Berea sandstone were thermally cycled to 675 and 385°C respectively. The Q of both rocks increased when measured over a broad range of relative humidities, but decreased at low humidities (10-25%). Measurements of adsorption isotherms for the Berea sandstone showed no loss of adsorptive capacity of the clays. Although the surface area of thermally cracked rocks increased, the number of sites where adsorbed water molecules contribute to attenuation decreased.

J. Geophys. Res., Red, Paper 1B0781

Planetology

6510 Atmosphere of planets
THE ALTITUDE DISTRIBUTION OF THE VENUS ULTRAVIOLET NIGHTGLOW AND IMPLICATIONS ON VERTICAL TRANSPORT
J.C. Gérard (Institut d'Astrophysique, Université de Liège, 4200-Cointe-Liège - Belgium) A.I.F. Stewart and S.W. Bougher

The altitude distribution of the nitric oxide nightglow has been measured with the ultraviolet spectrometer on board Pioneer Venus. Limb profiles obtained near periapsis with a ~4km vertical resolution have been fitted using a method independent of the spacecraft attitude data. It is found that the altitude of the maximum of the layer is 115±2 km and the topside scale height ~3km. It is shown that downward transport by diffusion alone is insufficient. If vertical motion is parametrized by eddy diffusion, an eddy diffusion coefficient $K = 6^{+6}_{-4} \times 10^{12}/M^{1/2}\ cm^2.s^{-1}$ is deduced from the altitude of the layer.

Geophys. Res. Lett., Paper 1L0363

6510 Atmospheres of Planets
KRYPTON AND XENON IN THE ATMOSPHERE OF VENUS
T. M. Donahue (Department of Atmospheric and Oceanic Science, University of Michigan, Ann Arbor, MI 48109) J. H. Hoffman and R. R. Hodges, Jr.

Probable values of the mixing ratios of krypton and its isotopes on Venus by the Pioneer Venus large probe neutral mass spectrometer are reported. An upper limit to most of the xenon isotope mixing ratios is also set. Based on a ^{36}Ar mixing ratio of 30 ppm the krypton mixing ratio is probably 47 ppb and its upper limit is 69 ppb. The upper limit for Xe is 120 ppb but there is probably considerably less than 40 ppb. Atmospheric krypton and xenon on Venus exceed terrestrial values by factors of 3.5 and no more than 30, much less than the ratios for neon and argon. It appears that the noble gases on Venus have a large solar component compared to Earth and Mars.

J. Geophys. Res., Blue, Paper 1A0616

Physical Properties of Rocks

6190 Elasticity, fracture and flow
THE GLASS TRANSITION IN BASALT
M. P. Ryan (Geochemistry-Mineralogy Program, Dept. of Geosciences, The Pennsylvania State University, University Park, PA 16802) and C. G. Sammis

The glass transition has been experimentally detected in basalt as (1) an increase in the aggregate linear thermal expansion coefficient, (2) an abrupt change in the temperature dependence of Young's modulus, dE/dT, and (3) a change in stress relaxation behavior that effectively separates the T > T_G and T < T_G creep regimes. Transition temperatures determined by the respective experimental methods are: (1) 680 ± 15°C, by expansion dilatometry; (2) 715 ± 10°C, by acoustic spectroscopy, and (3) 725 ± 25°C, by stress relaxation. For olivine tholeiite from Kilauea Iki lava lake, Hawaii, thermal expansivity rises through the glass transition interval attaining α_V = 39.0 x 10^{-6} °C^{-1} at 850°C. For olivine tholeiites with moderate glass contents, the temperature dependence of the Young's modulus changes on either side of the inferred T_G of 725°C, and dE/dT = -0.071 kbar °C^{-1} for T < T_G, while dE/dT = -0.21 kbar °C^{-1} for T > T_G. Collectively, the mechanical results suggest that for Hawaiian olivine tholeiite at 1 atm. pressure, the principal material responses are: (1) elastic (T ≲ 600°C); (2) reduced creep (600 < T < 725°C); (3) glass transition (T ≃ 725°C); (4) enhanced creep (725 < T < 980°C); (5) partial melt (T > 980°C). Fracture surface morphologies developed during solidification suggest that the presence of the supercooled melt grain boundary phase may participate in the regulation of the thermal cracking process. Well-preserved fracture surfaces formed by incremental crack growth are found to be covered with striations that correspond to the inferred sequential ...

Geotectonics

Volume 14, Number 6, 1980

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Seismology

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Based on the assumption of the undamped propagation of Alfven waves between 2 and 5 R_S, the possible range of Alfven wave energy flux density at the base of a polar coronal hole has been deduced. It is concluded that extended heating above 2 R_S is needed to maintain the temperature maximum near 3 R_S and to supply energy for the formation of high-speed wind streams. The energy contribution of extended heating to high-speed wind streams may be greater than that of Alfven waves by direct momentum addition.
J. Geophys. Res., Blue, Paper 1A0874

Electromagnetic Radiation
THE SOLAR SPECTRAL IRRADIANCE 1200-3184A NEAR SOLAR MAXIMUM: 15 JULY 1980
G. E. Mount (Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309) and G. J. Rottman
Full-disk solar spectral irradiances near solar maximum were obtained in the spectral range 1200-3184A at a spectral resolution of approximately 1A from rocket observations above White Sands Missile Range, New Mexico, on July 15, 1980. Comparison with measurements made in 1975 and during solar minimum confirm a large increase at solar maximum in the irradiance near 1200A with no change within our measurement errors near 2000A. Irradiances in the range 1900-2100A are in excellent agreement with previous measurements, and those in the 2100-2500A range are lower than the Broadfoot values. We find agreement with previous values from 2500-2800A, and then fall below those values above 2800A.
J. Geophys. Res., Blue, Paper 1A0784

Electromagnetic Radiation
ESCAPING NONTHERMAL CONTINUUM RADIATION
W. S. Kurth (Dept. of Physics & Astronomy, The University of Iowa, Iowa City, IA 52242), D. A. Gurnett, and R. R. Anderson
Observations by the ISEE 1 plasma wave receiver reveal heretofore unreported details of the nonthermal continuum radiation from the earth. In particular, the higher frequency escaping component shows temporal and spectral features which are quite different from those of the lower frequency trapped emission. The higher frequency component is often clearly separated in frequency from the trapped component and high resolution spectrograms show that the escaping radiation consists of numerous narrowband emissions which drift slowly in frequency with time. The higher frequency component also exhibits greater temporal and spatial variability in both amplitude and frequency although the temporal variations are still quite smooth when compared to the more intense and higher frequency auroral kilometric radiation. Evidence is presented which clearly shows a direct connection between intense electrostatic emissions near the upper hybrid frequency and the escaping continuum radiation and strongly suggests the latter electromagnetic emission is generated through mode coupling with the upper hybrid waves.
The new ISEE observations of the escaping continuum radiation from the earth strongly suggest a close correspondence with the newly reported narrowband kilometric radiation from Jupiter. Both emissions are relatively narrowband and show slow variations in amplitude with time. In both cases, the narrowband radiation lies above the trapped continuum radiation and below the intense extraordinary mode emissions (auroral kilometric radiation at the earth and decametric radiation at Jupiter). Evidence from both planets suggest the radiation is generated by intense electrostatic waves near the upper hybrid resonance frequency in the vicinity of the plasmapause at the earth and at the outer edge of the Io plasma torus at Jupiter.

solid by considering the effect of a solid rotor on an otherwise uniform magnetic field. This approach has subsequently been extended by considering convection in an electrically conducting Boussinesq fluid in the presence of an imposed magnetic field. Nonlinear solutions for two-dimensional magnetoconvection show both steady and oscillatory behaviour. The results of a series of numerical experiments at a fixed Rayleigh number of 10^5 are presented and contrasted with predictions based on linear theory.
J. Geophys. Res., Red, Paper 1B0831

Tectonophysics

8110 Convection Currents
PARAMETERIZED THERMAL CONVECTION IN A LAYERED REGION AND THE THERMAL HISTORY OF THE EARTH
D. McKenzie (Bullard Laboratories, Dept. of Earth Sciences, Madingley Rise, Madingley Road, Cambridge CB3 0EZ, England) and F. Richter
Parameterized convective schemes for constant viscosity fluids are used to investigate the influence of layering on the relationship between the rate of heat loss from and heat supply to a number of convecting layers of different viscosity and thicknesses. Simple analytic expressions are obtained which accurately predict the behaviour to a step decrease in the heat supply, and show that layering considerably increases the response time. The same arguments are applied to a planet consisting of spherical shells. They show that the response of the Earth's heat loss to the decay of radioactive elements depends strongly on whether mantle convection extends from the core to the surface. If it does so the surface heat flux is only about 50% greater than the heat generation rate. But if upper and lower mantle convection occurs in two separate shells, as seismological and geochemical arguments suggest, the response time is increased. The present surface heat flux is then principally controlled by the thermal structure of the Earth at the time it was formed. The best estimate of the present ratio of the heat loss to heat generation is about two, and this value is consistent with the behaviour of an earth model consisting of a two layered mantle overlying a core.
J. Geophys. Res., Red, Paper 1B0819

8110 Convection Currents
ON SOME CONSEQUENCES AND POSSIBLE CAUSES OF LAYERED MANTLE CONVECTION
Frank M. Richter (Department of the Geophysical Sciences, University of Chicago) and Dan P. McKenzie
Laboratory and numerical experiments are used to study convection confined to discrete layers. The laboratory experiments, which use the water content of a predominantly glycerine solution as a way of establishing "chemical" density variations, show that convection will remain confined to superimposed layers when the chemical density contrast between layers is greater than the density change associated with the greatest temperature difference within the convecting system. The numerical experiments show a double thermal boundary layer at the interface between layers, a feature that would result in an average temperature increase near 700 km depth of about 500°C in the mantle, if the lower mantle is isolated as suggested by recent geochemical models. The possible causes of a layered mantle convection system include major element chemistry variations, the combined effect of major element chemistry and a phase change or a phase change alone if it has sufficiently negative Clapeyron slope. (Layered mantle convection)
J. Geophys. Res., Red, Paper 1B0408

8140 Heat flow
A PLAUSIBLE TWO-DIMENSIONAL VERTICAL MODEL OF THE EAST MESA GEOTHERMAL FIELD, CALIFORNIA, U.S.A.
K.P. Goyal (Earth Sciences Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720) and D.R. Kassoy
A two-dimensional conceptual model of the East Mesa Geothermal system is developed on the basis of existing geological, geophysical, geochemical, heat flux, and borehole logging data. Hot water rising in a set of faults is assumed to charge the reservoir, which is overlaid by a clay-rich cap. The temperature-depth distribution observed at the site implies that the liquid is convecting at a high Rayleigh number. In this approximation, liquid rises up the fault and spreads isothermally into the nearby sections of the reservoir. The cooling effect of the surface on the flow in the reservoir is confined to a thin layer adjacent to the cap-reservoir interface near the fault. This layer grows with the distance from the fault. Eventually, the entire depth of the reservoir is cooled by the surface. The mathematical model is based on the flow of liquid water in a saturated porous medium. Results are obtained for the velocities, pressures, and temperatures in the entire system consisting of fault zone, aquifer, and clay cap. Finally we compare the predicted surface heat flux to that measured at the site in shallow wells. It is concluded that the model represents a plausible description of fault zone controlled systems like that at East Mesa.
J. Geophys. Res., Red, Paper 1B0706

8130 Heat flow
OCEANS AND CONTINENTS: SIMILARITIES AND DIFFERENCES IN THE MECHANISMS OF HEAT LOSS
J. Sclater (Department of Earth and Planetary Sciences, M.I.T., Cambridge, Mass., 02139, USA) C. Jaupart, and D. Galson
The principal objective of this paper is to present a simple and self-consistent review of the basic physical processes controlling heat loss from the Earth. To accomplish this objective we give a short summary of the oceanic and continental data and compare and contrast the respective mechanisms of heat loss. In the oceans we concentrate on the effect of hydrothermal circulation and on the continents we consider in some detail a model relating surface heat flow to varying depth scales for the distribution of potassium, thorium and uranium. From this comparison we conclude that the range in possible geotherms at depths below 100 to 150 km under continents and oceans overlap and that the thermal structure beneath an old stable continent is indistinguishable from that beneath an ocean were it at equilibrium. Oceans and continents are part of the same thermal system. Both have an upper rigid mechanical layer where heat loss is by conduction and a lower thermal boundary layer where convection is dominant. The simple conductive definition of the plate thickness is an oversimplification.
The observed distribution of area versus age in the oceans allows us to investigate the dominant mechanism of heat loss which is plate creation. This distribution and an understanding of the heat flow through oceans and continents can be used to calculate the heat loss of the Earth. This heat loss is 10 x 10^{12} cal/s (4.2 x 10^{13} W) of which more than sixty percent results from the creation of oceanic plate.
The relation between area and age of the oceans is coupled to the ridge and subducting slab forces that contribute to the driving mechanism for plate motions. These forces are self-regulating and maintain the rate of plate generation required to achieve a balance between heat loss and heat generation. (Heat flow, thermal structure, area-age.)
J. Geophys. Res., Red, Paper 1B0928

8150 Plate tectonics
THE EFFECTS OF HOTSPOTS ON THE OCEANIC AGE-DEPTH RELATION
R. Heestand (Dept. of Geological and Geophysical Sciences, Princeton University, Princeton, NJ 08544) S.T. Crough
Hotspots located both midplate and on midocean ridges can bias the empirical age-depth relation. Ocean floor bathymetry for seafloor greater than 80 mybp in age has been previously